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ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

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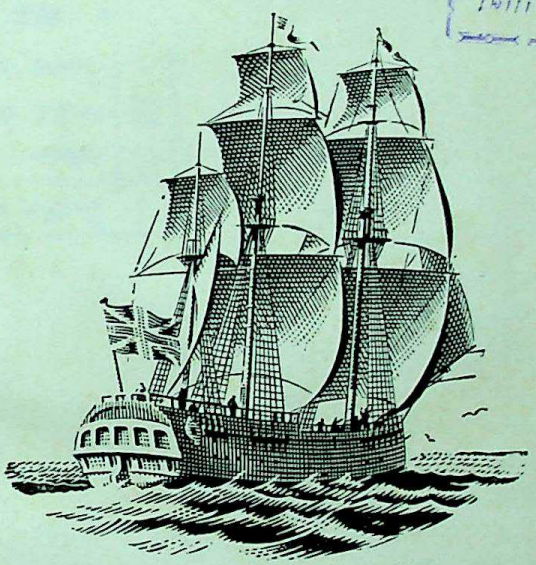

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ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

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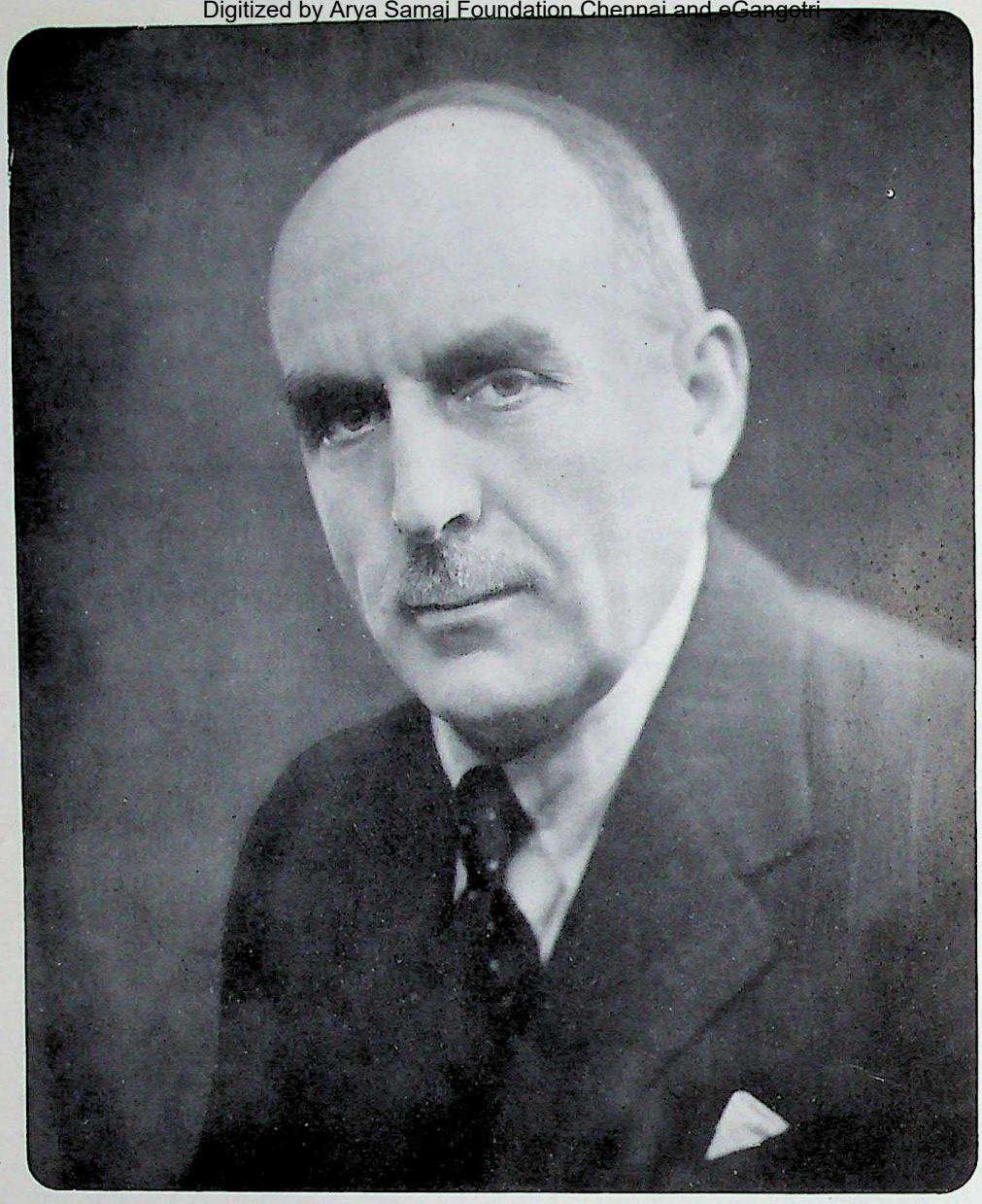

THE ASTRONOMER ROYAL

Dr Spencer Jones, author of the main article in this issue, has been Astronomer Royal since 1933. This is the premier as well as the best known astronomical appointment in Great Britain, and perhaps in the whole world, on account of its seniority and the number of distinguished men who have held it.

The first holder was John Flamsteed, appointed Astronomical Observator in 1675, whose name is immortalized in a series of observations from which modern astronomy may be said to have begun. His successor Edmund Halley (1720-42) was equally famous both for the discovery of the comet which bears his name and for his investigations of the tide. Other eminent holders of the appointment were James Bradley, Nevil Maskelyne, John Pond and Sir George Airy.

The Astronomer Royal works in the Royal Observatory at Greenwich, which is the foremost international station for the measurement of time.

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Our purpose

It is the duty of a new periodical on its first appearance to make declaration of the purpose for which it has been born. We are happy to do this by reference to a letter from PROFESSOR A. V. HILL, Secretary of the Royal Society, which is to be found in our Correspondence columns. Professor Hill recalls that in the year 1768 the great British navigator, Captain James Cook, set sail from England in the barque *Endeavour* to chart the South Pacific Ocean and observe the transit of Venus. He was accompanied by several men of science, including Sir Joseph Banks, a celebrated botanist of the period.

There are two or three things about this enterprise which are worthy of notice today. There is the continuity of the close association of the Royal Society with British scientific developments throughout the two hundred and eighty years of its existence. Sir Joseph Banks was President of the Society from 1778 to 1820, and Captain Cook was elected a Fellow in 1776 in recognition of his services to science. We are proud to be able to publish messages from today's President, SIR HENRY DALE, as well as from the Secretary. Then there is the evidence of the democratic spirit which animates the history of the British peoples, and has resulted in the emergence of many of our greatest men from humble surroundings. Cook was the son of an agricultural labourer and began his career as an apprentice in a coasting collier. Yet these undistinguished antecedents did not prevent him from entering the Royal Navy nor, once he was in it, from advancing so rapidly that he was no more than 40 years of age when he was appointed to command an expedition organized specifically for scientific purposes. And that is the third and, so far as we are here concerned, the most significant fact: that nearly two centuries ago the British Admiralty should see fit to equip a vessel and finance a cruise for the express purpose of carrying out exploration and research in the interests of science. It was only a small vessel, a sketch of which appears on our cover, but the fact remains that it carried overseas British men of science bent on making investigations for the advancement of learning.

We accept a like responsibility, and hope to be able to justify Professor Hill's confidence that our ENDEAVOUR will act as a vessel to carry overseas news of the continuing vitality and progress of the sciences, which know no frontiers but are directed to improving the common lot of all men. Our purpose is briefly to enable men of science, and particularly British men of science, to speak to the world in an hour when not only nations but the internationalism of the sciences are threatened by a recrudescence of barbarism in its grossest and most destructive manifestation.

Science is not the product of any one race, or of any one age. The Egyptians were the first agriculturists, the Babylonians the first astronomers, the Greeks mathematicians and physicians, the Arabs chemists: every country of Europe has played its part in pushing forward the frontiers of scientific knowledge; and the New World has proved itself the peer of the Old. Britain, however, may contemplate with particular pride the disproportionately long list of her sons who have made outstanding contributions to natural knowledge—a fact to which we are able to direct attention elsewhere in our columns—beginning with Roger Bacon in the thirteenth century and continuing with his even more famous namesake Francis, Newton, Boyle, Hooke, Mayow, Dalton of atomic theory fame, Davy, Faraday, Darwin, Thomson, and countless others. There is no country with a record more brilliant, and the torch is still carried high.

It is the aim of ENDEAVOUR to see that in these dark days its light is thrown overseas, especially to those parts of the globe where intimate contact with Great Britain is at present more difficult to maintain. We do not apologise if these pages lay emphasis on British scientific work. That is our particular pride. But that they will not be marked by any narrow insularity is, we are confident, sufficiently guaranteed by the contents of this inaugural number.

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Science and the community

SIR WILLIAM BRAGG

The present position of science and the applications of science are causing many of us to think furiously. The conclusions that are reached are varied; often they are mutually contradictory. It is clear that thinkers are starting from differing premises, which must be imperfect in some cases, and are influenced by different outlooks on life.

What Hitler thinks is plain enough. He and his people have grasped the fact of the tremendous powers of science in war. The German scientist has been put to the study of every form of natural knowledge which can enable the Nazi forces to wound, crush, and kill their opponents. Science has been applied to the design of ever more powerful guns, not to the increase in the supply of butter for the health and well-being of the people. Health is indeed considered, and nutrition is studied to an extent which can be an example to other nations, but the man is to be healthy and strong so that he may be a good soldier of a Reich trampling on the rest of the world. The great and ever-growing powers of science are understood, but the ideals are desperately wrong. Our side of the war shows an equal appreciation of science, later in time than that of the enemy, but not less thorough. Indeed, we begin to think that in some respects we are leading. The Allies are fighting for a better world than Hitler has in mind. To achieve it we must beat him with his own weapon.

What about the ordinary man, ordinary in the sense that he has not spent many years at school and is now earning his living as artisan or clerk or shopkeeper, or, it may be, is enlisted for the duration of the war? He is by no means inappreciative of what science can do: the wireless set and the aeroplane are continually before him as efficient witnesses. He does not know much about the patient development of the laboratory which has made such things possible. He is quite capable of understanding the part that science now plays in the nation's affairs, in his own business and his trade, in his home and his food, in the well-being and happiness of himself and his children; and he can be made to see that those whom he elects to be his governors must understand it also.

There were once theologians who looked on all science as a deadly enemy. But the clamour of that unfortunate battle has largely died down. The religious leader and the scientist continually find themselves fighting side by side for the alleviation of want and distress and for the prevention of disease. There at least their common purpose brings them together and the discord is resolved.

What are the thoughts of the man of the public school brought up on an old tradition which was indifferent to natural knowledge? He believes, and rightly so, that he guards an ancient and imperative knowledge of men which must not be dethroned. But the old system has been too engrossed in itself. From sheer refusal to see and consider the vast changes that have been coming over the world, it has difficulty in accommodating itself to them. There is change nevertheless, and that is very welcome, for we must have the spirit which the old education was meant to inspire. Science is not incapable of becoming a new source of that spirit; but how much more helpful and effective it will be if we all march together!

There is the industrialist, the employer of labour. In these recent years he has in general become aware of the powers of science in his business. Scientific research is a part of the machinery of nearly every industry; its adoption as such was doubtless due in considerable measure to the lessons of 1914-18. It is to the honour of many leaders of the business world in this country that they have seen how the selfish use of science can end in a cruel tyranny, and have laboured to devote it to the well-being both of those whom they serve and of those whom they employ.

What does the politician think about science? His thoughts are clearly very varied and his ideas of its use are often ill defined. That must be so since our rulers are drawn from different groups of men, including those already mentioned. The one group that is sparsely represented in Parliament is that of the scientists themselves. The present House contains only one who can be described as a working scientist. Consequently there are some who are

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suspicious of science, being ill acquainted with it, and others who have a vision of what may be accomplished by its means. Perhaps the majority suspends judgment. Departments of State are unavoidably dependent on science in these days: some welcome it and make good use of it. Others reluctantly admit it into their service.

Lastly, what does the scientist think himself, and what is his purpose? Of course, he must generally make his living by his work, and his thoughts may go no further for most of the time. But all scientists have at least an occasional vision of a vast and right use of their science for the benefit of mankind, and sometimes they can so display their vision that they carry the world with them.

Can we bring these very different thoughts into harmony by amending and enlarging the knowledge on which they are based? Can we bring it about that the politician and the man in the street, the theologian and the man of letters, the industrialist and the soldier, and the scientist himself, are so well informed that their thoughts are interchangeable? Can we induce each type of man to speak with sympathy for the various conditions and minds of those whom he addresses?

We must show that it is possible to observe the past growth of scientific ideas from the time of their inception through their development by thought and experiment and practice until they influence the minds of men and affect their lives. We must show how the present growth is to be watched so that the right advantage may be taken of it; we have to ward off the plunderers from the harvest and see that it is reaped for the well-being of men.

This magazine, of which the present number is the first to be issued, is an endeavour to add to the common understanding of science and of its influence upon the community. The founders are moved by conviction that this understanding is now of vital importance, and their earnest wish to contribute thereto is represented in the title under which their effort appears.

Correspondence

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., c/o Imperial Chemical Industries Limited, Nobel House, Buckingham Gate, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

MESSAGES OF WELCOME

From Sir Henry Dale, C.B.E., M.D., D.Sc., LL.D., F.R.C.P., *President of the Royal Society*

I am glad to have the opportunity of wishing all success to the new scientific quarterly ENDEAVOUR. Now, of all times, it is important that we should be reminded that science has still its proper uses, for the saving and the enrichment of human life, and for the enlargement of man's knowledge and understanding of his material environment. It is a matter for congratulation that British enterprise can now be made available to keep these permanent values before the eyes of the world.

From A. V. Hill, M.A., Sc.D., O.B.E., F.R.S., M.P., *Secretary of the Royal Society*

In 1768 CAPTAIN JAMES COOK (F.R.S. 1776), accompanied by SIR JOSEPH BANKS (F.R.S. 1766, President 1778-1820) and other scientific men, set sail in the *Endeavour* to observe the transit of Venus and explore the South Pacific Ocean. May your ENDEAVOUR record discoveries as famous as those made by Captain Cook!

From Sir Robert Robinson, M.A., D.Sc., Hon. LL.D., F.I.C., F.R.S.

It is perhaps not generally known that Imperial Chemical Industries, in addition to sponsoring

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and financing specific investigations, have made considerable annual grants to heads of university laboratories with the object of promoting research activities generally.

The foundation of ENDEAVOUR shows a further generous recognition by the corporation of the importance of encouraging scientific workers and of making the results of their labours known far and wide. British chemists welcome this enterprise and wish it every success. It will foster international intellectual co-operation, and there is a definite need for a journal of reviews of recent progress designed not so much for the specialist as for the general scientific reader.

From Sir Richard Gregory, Bt., F.R.S.

The publication of a quarterly scientific review having the scope and intention of ENDEAVOUR will be warmly welcomed by students of science everywhere, whether engaged in teaching or research, or as laymen watching with intelligent concern the growth of natural knowledge and its influence upon intellectual and industrial expansion. The review will be a survey of progressive scientific thought and work, with particular reference to British achievements and their contacts with scientific discovery and development throughout the world. I like to think of it as providing what has long been wanted—a medium which reflects with clearness and authority both academic learning and technological advances related to it. The magazine can thus represent a federation of British science and industry and undertake the functions of a university extension organ in the broadest sense.

Twenty years ago, the late MR E. W. SCRIPPS —a well-known newspaper proprietor and editor—placed the sum of £100,000 at the disposal of a board of trustees in the United States to promote the education of the community in the scientific factors which vitally influence human welfare and progressive development. The news agency entitled *Science Service* was founded with these objects and has become a very effective means of interpreting scientific discoveries and inventions of every kind to the general public. It is in the same spirit that Imperial Chemical Industries decided to establish a scientific quarterly which will provide authoritative articles of permanent value for readers whose minds require something more than transient news or sensational announcements. As the review is to be published in Spanish, French, and German, as well as in English, its appeal and its influence will be much more than national, and the response to them will be world-wide from all who cherish the pursuit of knowledge, either for its own sake or for its applications.

From Sir John Russell, D.Sc., F.R.S.

Scientific activity is now so widespread and so far reaching in its effects on human life that public knowledge of its results, and some directive organization of its efforts, have become indispensable. Any kind of organization that tended to hamper the freedom of the scientific worker in thought, expression, or investigation would, however, be fatal. The best type of direction in science is that which grows out of full, free, and frank discussion illuminated by well-designed experiments; the dominating purposes must be the search for truth and the promotion of human welfare. In so far as the journal can achieve these aims it will deserve and will secure all good wishes for success.

From Sir Joseph Barcroft, C.B.E., F.R.S.

I wish the journal every possible success, and I do not doubt that it will have a useful and brilliant future. I hope the years ahead of us after the war may bring about a large expansion of British applied science—more especially in the very high-grade lines in which some other nations have been ahead of us in practice, if not in theory.

From Sir James Jeans, O.M., F.R.S.

Everything is to be welcomed which will make our own nation more acquainted with the methods and results of science, will inculcate a scientific method of approach to practical and social problems, and above all will help to make the beneficent advances of science the common property of all nations and of all races. For these reasons I welcome the appearance of ENDEAVOUR, and wish it outstanding success.

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NATIONAL PARKS

From Julian S. Huxley, M.A., F.R.S., *Secretary of the Zoological Society of London*

In the spate of projects for reconstruction, I hope very much that the question of the conservation of wild life will not be overlooked. Considerable steps have been taken towards this, notably the establishment of National Parks, such as the Kruger National Park in South Africa, the Parc National Albert in the Belgian Congo, and various National Parks in Canada and the U.S.A.; and also the important London Convention Relative to the Preservation of Fauna and Flora (Africa), which came into force in 1936.

However, Great Britain, though it has taken the lead in securing the African Convention and in preparing to set up similar conventions for Asia and other parts of the world, is very behindhand in the matter of National Parks, both in Britain itself and in the Colonial Empire.

From the point of view of biological interest, the establishment of National Parks in the Colonies is obviously the more important. We have, in various parts of the Colonial Empire, and notably in East Africa, an unrivalled assemblage of interesting wild species which, however, is slowly but surely dwindling before the inroads of commercial and social development. These wild species constitute an irreplaceable heritage for the whole world, of the greatest scientific value; in addition, as anyone who has seen herds of big game in Africa can testify, they constitute a spectacle of unrivalled interest which, if properly conserved, can become the basis of a valuable tourist industry. The question of delimiting and establishing National Parks in the tropics is intimately bound up with science, since it is essential that proper surveys should be made of areas suitable for National Parks, to make sure that they do not contain reserves of valuable minerals, etc., which ought to be exploited in the interests of the world.

Another scientific aspect of the question, which is often neglected, is that of the scientific management of nature reserves and National Parks. Once man steps in, the balance of nature is distorted, and without careful management, undesirable or relatively uninteresting species may multiply at the expense of desirable or more interesting ones. This is especially true in small nature reserves in civilized countries, but applies also to a considerable degree even in large tropical areas. The problem is an ecological one which involves careful study both by botanists and zoologists, while the sociological aspects of the matter should also not be neglected.

CO-OPERATION BETWEEN UNIVERSITIES AND INDUSTRIAL TECHNICAL STAFF

From E. N. da C. Andrade, D.Sc., Ph.D., F.Inst.P., F.R.S., *Quain Professor of Physics in the University of London*

I think that it will be generally agreed that a closer connection between the industrial laboratories and the scientific departments of the universities is a thing greatly to be desired after the war. In the course of my present work I have had to visit the laboratories of various large concerns which I did not normally enter and have been struck by the wide scientific interest of much of the work in hand—an interest wider than those engaged in it always realize—and by the friendly eagerness with which suggestions have been received. My experience is, I believe, a usual one. I take it, then, that the necessary state of mind exists on both sides for cordial co-operation, but I have not so far seen any specific plans for putting into effect the desired collaboration.

After the last war a plan was tried of having work carried out in university laboratories, under the general supervision of university professors, by scientists in the employ of industrial firms. This, if successful in some cases, certainly was not in all. It has occurred to me that a modification of this plan might be tried, namely to have certain researches which are being carried out in the laboratories of industrial concerns and research associations put under the general guidance of university professors or other teachers.

I am not thinking, of course, of the main lines of research of the laboratory in question, which are being pursued by teams of specialized workers under experts of proved achievement and long experience, but rather of inquiries, initiated on points a little removed from these main lines, which are occasionally entrusted to comparatively junior workers, whose general

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scientific experience and knowledge of the particular subjects are sometimes a little limited. Be that as it may, what I contemplate is that the laboratory shall invite an academic expert who enjoys their confidence to co-operate in the planning of the particular piece of work, and subsequently to visit the laboratory at convenient intervals, to guide, or take part in guiding, the progress of the investigation. From such visits one might hope to see grow up spontaneously, under natural conditions, a wider co-operation. Common interest in a definite inquiry, however small, would lead, if the original choice had been wisely made, to more extended sympathies. Our commercial laboratories possess an immense store of specialized knowledge and leaders of great insight, but occasionally a fresh point of view, such as may occur to one not in daily contact with the subject, is stimulating.

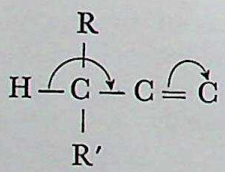
Even if the suggestions made in this letter fail to win support, I trust that it may nevertheless serve a purpose by directing the attention of more fertile and experienced minds to finding an easy and practicable way of bringing about the desired co-operation.

Work in progress

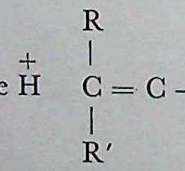
POLAR EFFECTS OF ALKYL GROUPS

Contributed by J. W. Baker, M.A., Ph.D.

To explain why the order Bu$^{\gamma}$ > Pr$^{\beta}$ > Et > Me for the electron-release of alkyl groups by the inductive mechanism is sometimes upset and even completely inverted, J. W. BAKER and NATHAN (*J. Chem. Soc.*, 1935, 1844) postulated a superposed electron-release by a tautomeric mechanism arising from conjugation of the electrons of the C–H bond with an attached unsaturated system—



This should include a mesomeric (polarization) effect, operative in the ground states of such molecules and arising from resonance involving structures of the type

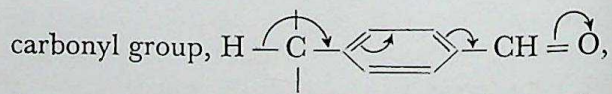


and an electromeric (polarizability) effect operative only in the transition complexes of reactions which require such electron-release (Baker, *ibid.*, 1939, 1150). Such tautomeric effects would give rise to electron-release decreasing in the order CH_3 (R′ = R = H, three such bonds) > CH_3CH_2 (R = CH_3, R′ = H, two such bonds) > $(CH_3)_2CH$ (R = R′ = CH_3, one such bond) > $(CH_3)_3C$ (no such bond).

An *electromeric* effect decreasing in this order has been verified by Hughes, Ingold and Taher (*ibid.*, 1940, 949) in the unimolecular solvolysis of *p*-alkylbenzhydryl halides. To establish the reality of the *mesomeric* effect BAKER and (MISS) HEMMING are making a study of the equilibrium

$$p\text{-}RC_6H_4.CH{:}O + HCN \underset{k_2}{\overset{k_1}{\rightleftharpoons}} p\text{-}RC_6H_4.CH(OH)\text{-}CN$$

(R = alkyl), in which only the relative energy levels of the ground states of the aldehyde and its cyanohydrin are involved. It is anticipated that the mesomeric electron-release would be more important in the aldehyde since here conjugation the C–H bonds extends to the side-chain carbonyl group,



whereas in the cyanohydrin it is limited to the benzene ring. The *p*-alkyl substituent should thus stabilize the aldehyde relative to its cyanohydrin in the order Me > Et > Pr$^{\beta}$ > Bu$^{\gamma}$ and such differential stabilization should be revealed in the values of $\Delta F = -RT\log K$. Experimental methods have been worked out whereby the values of the equilibrium constant K and of the velocity coefficients k_1 and k_2 can be determined at different temperatures, and the results so far obtained confirm the expected order of mesomeric electron-release.

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The distance of the Sun

H. SPENCER JONES

The Astronomer Royal has recently completed the most accurate determination yet made of the Sun's distance from the Earth, from data based upon co-operative work at twenty-four observatories scattered over the five continents. The Sun's distance is the fundamental distance in astronomy and enters into any calculation of distances and masses, of sizes and densities, of planets or their satellites, or of stars. The scale of the whole universe is built up on this distance. The new result is an outstanding British contribution to science.

The problem of the determination of the distance of the Sun is one of the most important in astronomy. This distance provides our standard yard-measure, on which the measurement of all distances in the universe is based. It is the fundamental datum in astronomy and enters into almost any calculation of distances and masses, of sizes and densities either of planets or of their satellites, or of the stars. Any error in its determination is multiplied and repeated in many different ways, both in the solar system and in the universe as a whole. In all ages the Sun's distance has been the object of inquiry, and it still attracts the attention of astronomers because the problem of its determination to an accuracy of one part in a thousand presents great inherent difficulties. An error in measurement that would set the Moon nearer to or farther from us than she really is by 100 miles would produce an error of 16,000,000 miles in the distance of the Sun. A new determination of this distance, based on investigations that have extended over twelve years, has just been completed and has provided by far the most accurate measure of the Sun's distance ever made. The distance proves to be 93,005,000 miles with an uncertainty of only 9,000 miles.

If the distance of the Sun is to be determined by direct observation, it must be by the measurement of an angle. This is exactly what the surveyor does in the measurement of the Earth's surface by the process called triangulation. He starts with an accurately measured base-line and determines the distance of a distant point by measuring, from each end of the base-line in turn, the angle between the base-line and the direction to the distant point. This enables him to calculate the distance of the point from each end of his base-line; these distances he uses as new base-lines for measuring the distances of more distant points and so on. In the case of the Sun, the angle to be measured is what is called the *horizontal parallax* of the Sun; it is the amount by which the Sun at rising or setting is apparently moved—to an observer on the rotating earth—from his true place in the heavens. This angle of parallax is the angle subtended by the radius of the Earth as seen from the Sun and is measured by the ratio of the radius of the Earth to the distance of the Sun. The dimensions of the Earth are known with great accuracy, so that the measurement of the Sun's parallax determines his distance. The angle to be measured is about equal to the diameter of a halfpenny as seen 2,000 ft. away, and it is this small angle that the astronomer endeavours to measure to an accuracy of one part in a thousand.

The Sun is a difficult object for accurate measurement under the best conditions; his large size and the effect of his heat on the instruments used reduce the accuracy of measurement. At rising or setting, when the angle of parallax is largest, the difficulties are greatly increased because we then view the Sun through a great depth of atmosphere, with disturbing effects due to refraction by the atmosphere and to the passage of the Sun's rays near the warm surface of the Earth. If the distance of the Sun could not be determined otherwise than by direct observation of the Sun, it would be a vain hope to expect an accurate answer. But fortunately, this is not necessary because, if the distance of any single object in

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the solar system can be measured, the distance of the Sun can be inferred. This is made possible by means of the famous third law governing the motions of the planets, discovered by JOHANN KEPLER (1571–1630) in the year 1618. The law was deduced by Kepler from a study, extending over many years, of the observations by the great Danish astronomer, TYCHO BRAHE (1546–1601), who first introduced accuracy into the measurement of astronomical positions. It was enunciated by Kepler in the following form: the periodic times of any two planets are to each other exactly as the cubes of the square roots of their median distances.

The periodic times taken by the planets to describe their orbits around the Sun can be measured without difficulty and with great accuracy. Hence, by this law of Kepler, their *relative* distances can be inferred. The solar system can therefore be readily drawn to plan; the scale of the plan is fixed as soon as any one distance in it has been measured. The smaller the distance, the more favourable are the circumstances for accurate measurement, because the angle of parallax—from which the distance is inferred—is larger in relation to the errors of observations. From time to time, one or other of the planets in their unending journey round the Sun comes sufficiently near the Earth to enable the Sun's distance to be measured with reasonable accuracy.

But let us first go backwards in time and see what had been learnt about the distance of the Sun before the enunciation by Kepler of his third law gave astronomers this latitude in choice of method of attacking the problem. The first attempt at an estimate of the Sun's distance was made by the Greek astronomer, ARISTARCHUS OF SAMOS, in the third century B.C. In figure 1, S denotes the Sun and M the Moon. E is the position of an observer on the Earth. The Sun illuminates the half of the Moon's surface that faces it, the other half being in darkness. It is obvious that, if the angle SME is a right-angle, the observer at E will see exactly one half of the Moon's face illuminated. The appearance of the Moon is then that known as first quarter. If the distance of the Sun ES were four times the distance of the Moon, the angle SEM would be 75°. The smaller the distance of the Sun, the smaller

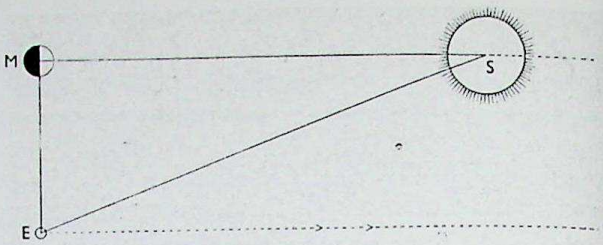

FIGURE 1 – *The method used by Aristarchus to compare the distances of Sun and Moon from Earth. (The sizes and distances are not drawn to scale.)*

this angle will be; if, on the other hand, the distance of the Sun is very great in comparison with the distance of the Moon, the angle MES will be nearly a right-angle. A small error in measuring the angle will then produce a large error in the distance ES. Aristarchus measured the angle MES and obtained 87°; he concluded that the distance of the Sun was nineteen times the distance of the Moon. This distance is about twenty times too small. The true value of the angle MES is 89° 51′ and is so near to 90°—which would place the Sun at an infinite distance—that it was not possible for Aristarchus to determine the distance of the Sun with any accuracy. The method is ingenious and is correct in theory; but in practice it is unreliable, for the boundary between the illuminated and dark portions of the Moon's face is not sharply defined and it is impossible to decide exactly when the face appears half illuminated. Figure 2 shows the appearance of the Moon at first quarter and the ill-defined boundary between the illuminated and dark portions.

In the second century B.C., the Egyptian astronomer PTOLEMY, using observations by Hipparchus of some partial eclipses of the Moon, determined the Moon's distance with fair accuracy. Combining this result with that obtained by Aristarchus he obtained a distance for the Sun about 1,200 times the radius of the Earth, or somewhat less than 5,000,000 miles. This result was accepted without question until the end of the sixteenth century, so great was the authority of the Greek astronomers. At that time Kepler was engaged on his investigations of the observations of the positions of the planets made by Tycho Brahe. In the course of his researches on the motions of Mars, he

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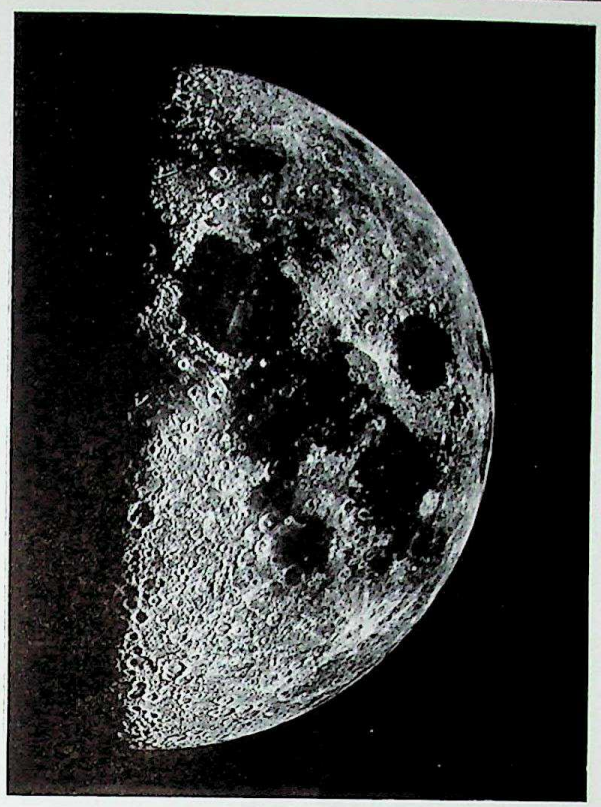

FIGURE 2 – *The Moon at first quarter.*

came to the conclusion that the distance of the Sun must be much greater than had been supposed; he estimated that its distance was between 3,500 and 7,000 times the Earth's radius (i.e. between 14,000,000 and 28,000,000 miles), an estimate which still fell far short of the true distance, though a considerable improvement on Ptolemy's value.

A much better estimate was made by the famous Dutch astronomer CHRISTIAAN HUYGENS (1629–95), not by direct measurement but by an ingenious argument. The apparent sizes of the planets were measured by him with his telescope. Since, as we have already explained, Kepler's third law makes it possible to draw the solar system to scale, Huygens was able to estimate the relative sizes of the planets, with the exception of the Earth. He then assumed that the Earth was intermediate in size between its adjacent planets Venus and Mars, and thereby fixed the scale of the whole solar system. He concluded that the Sun's distance was 25,086 times the Earth's radius, or about 100,000,000 miles. This near approach to the true distance was somewhat fortuitous. The diameter of the Earth is actually rather larger than that of Venus and nearly double that of Mars, so that the assumption made by Huygens was considerably in error; but the poor quality of the early telescopes made the planets appear larger than they are, and this defect, by chance, approximately compensated for his underestimate of the size of the Earth in relation to Venus and Mars.

The two planets which appeared to offer the best scope for measuring the Sun's distance by direct observation were Mars and Venus. The orbit of Mars lies at one point only 34,500,000 miles outside the orbit of the Earth (see figure 5). When the two planets happen to arrive together at the points of nearest approach of their orbits, the best occasion is provided for determining the distance of Mars. At such times Mars is in opposition to the Sun, Mars, the Earth and the Sun being in line and Mars crossing the meridian at midnight. These favourable oppositions occur at intervals of fifteen or seventeen years, in August. Such an occasion occurred in 1672 and was used to provide the first scientific estimate of the Sun's distance. The observations were planned by GIOVANNI DOMENICO CASSINI (1625–1712), the first director of the Paris Observatory, then just completed. An expedition was sent to Cayenne to make observations of Mars, whilst corresponding observations were made at the Paris Observatory; Paris and Cayenne thus formed the ends of a base-line, and from the difference in the direction of Mars as seen from the two places the distance was to be inferred. The result of the observations was to place the Sun at a distance of between 82,000,000 and 91,000,000 miles, with a probable value of 86,000,000 miles—a value that was accepted for about a century. In close agreement with this result was the determination later made by the ABBÉ LACAILLE (1713–62), who made observations of Mars during his visit to the Cape of Good Hope in 1750–52, which he compared with other observations made in Europe.

The orbit of Venus lies inside that of the Earth, so that Venus comes closest to the Earth when she passes between it and the Sun. Her distance from the Earth is then 26,000,000 miles, which is appreciably smaller than the distance of Mars. But Venus then becomes lost to sight

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in the rays of the Sun, so that it is only on the somewhat rare occasions when her path lies directly in front of the Sun and she can be seen to transit across the Sun's disk that measurements become possible. Four transits of Venus occur every 243 years, at successive intervals of 8, 105½, 8, and 121½ years. Five transits only have ever been observed, viz. the transits of 4th December, 1639; 6th June, 1761; 3rd June, 1769; 9th December, 1874; and 6th December, 1882. The next two will occur on 8th June, 2004, and 6th June, 2012.

The transit that occurred on 4th December, 1639 (or 24th November, Old Style), was seen by only two people, JEREMIAH HORROX (1619–41), 'the Keats of English astronomy,' and his friend, WILLIAM CRABTREE. Kepler had foretold that Venus would pass over the Sun's disk in 1631, and not again until 1761. The transit of 1631 occurred at night-time in Europe and could not be observed. Horrox recalculated the motion of Venus, found that the tables used by Kepler were in error and concluded that a transit should occur on 24th November, 1639. He was able to make successful observations of the transit at Hoole, in Lancashire, where he was curate, whilst his friend Crabtree, in Manchester, to whom he had confided his prediction, obtained through a break in the clouds one glimpse only of Venus on the Sun's disk.

The use of transits of Venus for determining the distance of the Sun was first pointed out by the celebrated mathematician JAMES GREGORY (1639–75) in his treatise *Optica Promota*, published in 1663. The same suggestion was made independently by EDMUND HALLEY (1656–1742), afterwards the second Astronomer Royal, in his *Catalogus Stellarum Australium*, published in 1679, and the peculiar advantages of this method of finding the Sun's distance were expounded by him in the *Philosophical Transactions of the Royal Society* in 1694 and 1716. As viewed from remote parts of the Earth, the track of Venus across the disk of the Sun will be different, and the times of the beginning and ending of the transit will be different (see figure 3). The differences of path or of time can be translated into differences of space, the distance of Venus relative to that of the Sun being known by Kepler's third law and the distance between the two places of observation being known from the dimensions of the Earth.

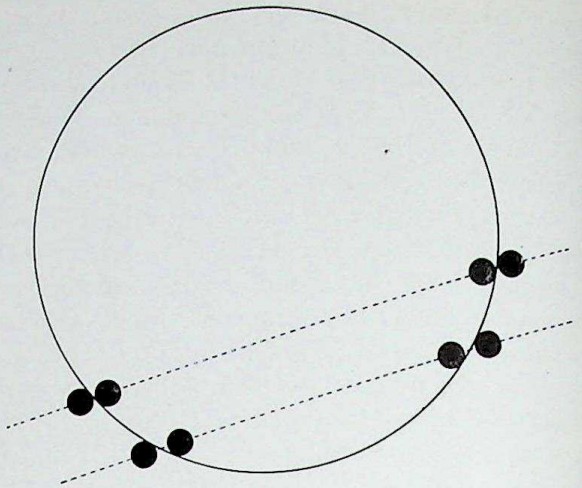

FIGURE 3 – *The external and internal contacts of Venus with the Sun, as seen from two different places on the Earth. The times of each of the four contacts are observed.*

Halley emphasized the advantages of basing the determination solely on the observations of the times of beginning and ending of the transit; these could be determined with accuracy, he said, 'without any other instruments than telescopes and good common clocks, and without any other qualifications in the observer than fidelity and diligence, with a little skill in astronomy.'

As the transits of 1761 and 1769 drew near, there were high hopes that this double opportunity of using the method suggested by Halley would very materially reduce the uncertainty in the Sun's distance. Nothing seemed easier than to note the exact instants when the small dark disk of Venus would be just in contact with the edge of the Sun's bright disk, as Venus approached and left the Sun. The principal governments of Europe fitted out expeditions to various parts of the world, observers being scattered to many stations over the face of the Earth. The occasions were amongst the first instances of international co-operation in astronomy, of which there have been many since, from which the science of astronomy has benefited and knowledge has been advanced. It is worthy of note that it was the transit of 1769 that gave CAPTAIN COOK his chance to establish his fame as a navigator. He took a party of observers in the *Endeavour* to Tahiti in the South Seas and, after the transit had been

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observed, completed his three-year voyage round the world. Mention may also be made of the ill fortune that befell the French astronomer LE GENTIL. He had intended to observe the transit of 1761 at Pondicherry, but the war between the French and English caused him to arrive too late. He decided to remain there for eight years to make certain of observing the transit of 1769, but clouds at the critical time prevented him from seeing anything. On his eventual return to France he found that during his long absence he had been adjudged legally dead and that all his property had been divided amongst his next-of-kin!

The results of these observations can only be described as disappointing. Unexpected difficulties were encountered in determining the exact instants of contact between the dark disk of Venus and the bright disk of the Sun. Instead of meeting and parting with the clean definiteness that had been looked for, they appeared to cling together, a black spot seeming to form between the edge of Venus and the edge of the Sun, somewhat as a drop of ink clings to a pen which is slowly withdrawn from an inkpot (see figure 4). The results obtained by the various expeditions were very different and discordant, and the uncertainty in the Sun's distance, instead of being reduced to a few hundred thousand miles, as had been confidently expected, remained at several millions. In 1822 ENCKE made a comprehensive discussion of all the observations that had been made at the two transits, endeavouring to co-ordinate the phenomena described by the various observers and to bring order out of confusion. He placed the Sun at a distance of 95,250,000 miles. Of this determination GRANT remarks in his *History of Physical Astronomy* (1852):

> When we consider the ingenuity of the method employed in arriving at this determination, and the refined nature of the process by which it is carried into effect, we cannot refrain from acknowledging it to be one of the noblest triumphs which the human mind has ever achieved in the study of physical science.

But this confidence that all was well was not to remain for long undisturbed. A Danish astronomer, PETER ANDREAS HANSEN (1795–1874), was engaged on the study of the complicated theory of the motion of the Moon, which culminated in some new tables of the

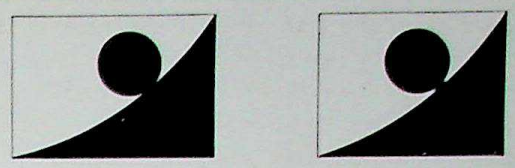

FIGURE 4 – *The appearance of the 'black drop' as the dark disk of Venus transits on to the bright disk of the Sun.*

Moon, published by the British Admiralty in 1857 and for which a grant of £1,000 was made to Hansen by the British Government. In 1854 Hansen announced that the observed motion of the Moon could be brought into accord with theory only if the Sun were appreciably nearer than it was then supposed to be. In the motion of the Moon, there is an effect arising from the fact that the attracting force of the Sun on the Moon is greater on the half of the Moon's orbit that lies towards the Sun than on the other half, because the Moon is nearer to the Sun in the former half than in the latter. This causes a disturbance in the motion of the Moon, with a period of a month, the Moon being more than two minutes behind at first quarter and at last quarter more than two minutes ahead of the position that it would occupy in the absence of this disturbance. The magnitude of the effect obviously depends upon the ratio of the distances of the Sun and Moon from the Earth and provides a means by which the distance of the Sun can be inferred, if observations of the Moon can be made with sufficient accuracy. The complicating factor is that around first quarter the position of the Moon must be determined from observations of one limb and around last quarter from observations of the other limb. Errors will be introduced if the angular diameter of the Moon is not known with very high precision, and the measurement of this diameter is made somewhat uncertain by the irregularities in the Moon's profile, caused by its very mountainous surface and by the fact that the Moon is not quite spherical. In 1858 LEVERRIER, Director of the Paris Observatory, found in this way a distance of 91,000,000 miles. The most exhaustive and complete determination by this method is one that the writer made ten years ago, based on observations of the position of the Moon from 1672 to 1908, which gave a distance of 92,940,000 miles, with an uncertainty either way of about 40,000 miles.

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Meanwhile another method by which the distance of the Sun could be estimated had become available. In 1675 OLAUS RÖMER had proved that light does not travel instantaneously, but with finite velocity. He found that the eclipses of Jupiter's satellites invariably occurred later than they should when the Earth was farthest away from Jupiter, and earlier than they should when the Earth was nearest. The difference in time, amounting to about 16½ minutes, represents the time taken by light to travel across the diameter of the Earth's orbit. This made it possible to determine approximately the speed with which light travels. In 1728, the phenomenon known as *aberration* was discovered by JAMES BRADLEY (1692–1762), afterwards Astronomer Royal. Bradley had been puzzled by certain anomalies in his measurements of the positions of stars; the stars seemed to be pushed out of their places, in the direction of the Earth's motion, by a small amount. When he had despaired of being able to account for these anomalies, the explanation came to him suddenly, when he was not in search of it. He had accompanied a party in a pleasure sail upon the River Thames and he noticed that, every time the boat put about, the vane at the masthead shifted, as though the direction of the wind had changed. He commented on this to the boatmen, who told him that the wind had not changed but that it was merely the effect of change of direction of the boat. He at once realised that the anomalies that had been puzzling him in the positions of the stars were due to an exactly analogous cause. Just as the direction in which the wind-vane pointed depended both on the direction of the wind and that of the boat, so the apparent direction in which a star is seen depends upon the motion of the Earth and the finite speed of travel of light. If the Earth stood still, or if light reached us from the stars instantaneously, there would be no 'aberration' in the star's apparent position. The amount by which the stars are displaced depends upon the ratio of the speeds with which the Earth and light travel, which is about one to ten thousand. If, then, the speed of light is known, the speed of the Earth can be deduced. But the speed of the Earth is related to the size of its orbit, for its orbital path is described in one year and, the speed being known, the size of this orbit and, consequently, the distance of the Sun can be inferred.

In Bradley's time there had been no direct measurement of the velocity of light, which could only be ascertained through the imperfect knowledge of the distance of the Sun. The first successful terrestrial measurements of the velocity of light were made by FIZEAU in 1849; since that date many measurements have been made and developments in methods and technique have brought about such an increase in precision that the velocity of light is now known to an accuracy of about one part in 100,000—a remarkable triumph of human ingenuity. It might be thought, therefore, that from the many determinations of the aberration of the stars the distance of the Sun could be found with very high precision. But this method proves to be attended with serious difficulties. The astronomer has always to consider carefully the errors to which his observations are liable, for these errors limit the accuracy of his results. All observations are subject to error to a greater or lesser extent, though, by careful choice of methods and arrangements of the observations, it is frequently possible to eliminate some sources of error and to reduce the effects of others.

The measurement of aberration depends essentially on the comparison of the apparent positions of stars obtained at an interval of about six months, when the Earth is at opposite ends of its orbit. This introduces all sorts of troublesome seasonal effects, caused by differences in climatic conditions, whose nature is very obscure and which are extremely difficult to control. The errors bound up with seasonal causes are amongst the most troublesome in astronomy. Because of the peculiar difficulty in eliminating them, aberration can be determined with greater precision by using the distance of the Sun found by other methods than by direct measurement. What is probably the most accurate determination of the Sun's distance by this method was derived by the writer from special observations at Greenwich, extending over twenty-five years from 1911 to 1936; and gave 92,930,000 miles for the Sun's distance.

By repeated determinations by various methods, the extreme limits for the Sun's distance were slowly narrowed. By 1870 it

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could be said with fair certainty that the Sun was not nearer than 91,000,000 miles and not more distant than 96,000,000 miles. The range in possible distance of 5,000,000 miles was still considerable. The transits of 1874 and 1882 were then near at hand; despite the unexpected difficulties experienced in 1761 and 1769, it was confidently expected that a final answer to the question of the Sun's distance would be given by these transits. More than a century had passed, and not in vain; there had been during that time many improvements in instruments, in methods of observation and in general technique. Photography was being developed as an aid to the astronomer and much was hoped from it; though there might be difficulty in co-ordinating and interpreting visual observations, the camera could not lie and would be free from bias.

And so the most intensive scheme of international co-operation that astronomy had yet seen was organized well in advance. The best practical methods of observation were considered by official commissions. The observers were trained beforehand by means of models, designed to reproduce as nearly as possible the expected appearances; the times of ingress and egress recorded by different observers were compared with the true times which, in the case of the model, were known. Thus it was hoped that the habit of each observer, what is known as his 'personal equation,' could be eliminated and used to correct his observations. Special instruments were made to ensure uniformity in equipment and method. England, France, Germany, Italy, Russia, Holland and the United States co-operated and some four score stations were occupied, at a cost of nearly a quarter of a million pounds. Siberia, the Sandwich Islands, Kerguelen and the almost inaccessible St Paul's and Campbell Islands were amongst the places to which expeditions were sent. The weather proved generally favourable; the well-organized arrangements proved equal to the test; the contacts were well observed and many photographs were obtained.

Yet the results proved a great disappointment. The black drop again gave trouble, but not more than was expected. More troublesome was the illumination due to the atmosphere of Venus, which caused the planet to be girdled by a ring of light. So uncertain were the instants of precise contact that observers with identical equipment, and standing a few feet from one another, recorded times that differed by as much as a minute. Photography, on which such high hopes had been based, proved an almost total failure. When all the observations had been co-ordinated, the results discussed, and the photographs measured, the uncertainty in the distance of the Sun remained at about 1,500,000 miles. The great campaign had failed to secure uniformity of judgment on the part of the observers and had contributed little to the precise knowledge of the Sun's distance.

But, undaunted, preparations for the second transit were pushed ahead—with abated enthusiasm, indeed, but with hope that the experience gained in 1874 would be of value. Another occasion would not arise for a century and a quarter, and this one could not be allowed to go by default. Some countries withdrew on the ground that other methods for finding the Sun's distance were more accurate and less costly. The arrangement of the observations was discussed by an international conference in Paris in 1881. Again there were many expeditions, the British parties being scattered from Queensland to Bermuda; visual and photographic observations were once more tried. The results were again disappointing; the distance of the Sun came out at about 92,500,000 miles, but the diversity of results given by the various expeditions and by different methods of discussion showed that no great confidence could be placed in this value. An uncertainty of not more than 100,000 miles had been hoped for; this had certainly not been attained.

But meanwhile other objects more suitable for observation than Mars or Venus had come within the range of celestial trigonometry. In the wide gap between the orbits of Mars and Jupiter there exists a swarm of tiny planets or asteroids circling round the Sun. The first to be discovered was found on the night of 1st January, 1801, by the Sicilian astronomer PIAZZI, and was named by him Ceres, after the tutelary deity of the island. Pallas was discovered in 1802 by OLBERS, Juno by HARDING in 1804, and Vesta by Olbers in 1807. These are the brightest of the asteroids and there were no further discoveries until Astraea was found by HENCKE in 1845. Three more were

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found in 1847 and there have been new discoveries every year since, so that about a couple of thousand are now known. Many others, extremely faint and tiny bodies, no doubt remain as yet undiscovered. These tiny planets are possibly the remnants of a former planet that has been disrupted. Most of the asteroids are of little intrinsic interest and the somewhat monotonous work of keeping track of them is carried on because from time to time one of them proves to be of special interest. In 1872 it was suggested by PROFESSOR GALLE of Breslau that some of the asteroids might repay astronomers for much of their disinterested toil in keeping track of them, by aiding their efforts to determine the scale of the solar system. Some of them are sufficiently bright and come near enough to be of use for this purpose, and, being small enough to appear like a star in the telescope, they have a distinct advantage over Mars or Venus, with their large discs. A co-operative scheme for observing the three asteroids Victoria, Iris, and Sappho, arranged by DR (later SIR DAVID) GILL, H.M. Astronomer at the Cape Observatory, and carried out in 1888 and 1889, gave a solar distance of 92,874,000 miles and was undoubtedly the most accurate determination that had been made up to that time.

The 433rd asteroid to be discovered, found on 14th August, 1898, and named Eros, proved to be of singular importance for measuring the Sun's distance. It is a small body, only some fifteen miles in diameter, with an orbit so elliptical that once in thirty years it comes within about 15,000,000 miles of the Earth (see figure 5). One such near approach had by bad luck occurred in 1894, shortly before its discovery. Since then its nearest approaches have been in 1901, when its least distance was somewhat less than 30,000,000 miles, and in 1931, when its least distance was only 16,200,000 miles, affording the most favourable opportunity that has ever occurred for determining the Sun's distance. The observations of Eros were far more numerous in 1931 than in 1901; the circumstances were far more favourable at the latter date because of the nearer approach of Eros to the Earth; the great advances made during the present century in the applications of photography to precise astronomical measurement have made greater accuracy possible in

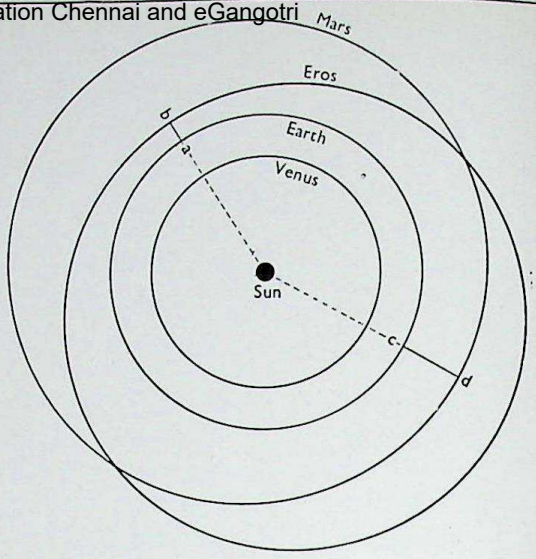

FIGURE 5 – *Orbits of Earth, Mars, Venus, and Eros.* ab *is closest possible approach of Eros to Earth,* cd *is closest possible approach of Mars to Earth.*

the more recent observations. The results derived from the 1931 observations will therefore alone be referred to.

The observations were almost entirely photographic; the method used was to photograph Eros and the surrounding stars on the same plate and then, by careful measurement, to determine its exact position among the stars. As this position differs slightly according to the situation of the observer on the Earth's surface, the comparison of photographs taken at two stations on the Earth's surface enables the relative displacement of Eros to be determined and the distance of the Sun to be inferred. Another method is to take two photographs from the same station, separated in time by a few hours. In the interval, the rotation of the Earth has carried the station some thousands of miles from its former position, so that it becomes virtually equivalent to a second station. A complicating factor is that the observations in the first method will not be exactly simultaneous, whilst in the second method they are separated by some hours, and during the interval both the Earth and Eros have moved somewhat along their orbits round the Sun. The displacement during this interval in the position of Eros as seen from the Earth must be allowed for. This is not a matter of great difficulty when the paths of Eros and the Earth around the Sun are accurately known. Now it

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is usually stated that the path of a planet round the Sun is an ellipse. This would be so if there were no other planets. But gravitation is a universal force. It is the gravitational pull of the Sun that compels the Earth to travel around the Sun in an elliptical orbit; but all the while each of the other planets of the solar system is also exerting its gravitational pull on the Earth, which depends on the distance of the other planet from the Earth and is continually changing as the distance changes. The effects of the gradually varying pulls of each of the other planets on the Earth and on Eros must be determined and taken into account when calculating the paths of the Earth and of Eros. This is a long and intricate task.

The positions of all the stars, several thousands in number, which are used as reference points for determining the positions of Eros in the sky, must be derived by special observations. In this lengthy piece of work, thirteen different observatories co-operated, the results being co-ordinated and combined to form a general catalogue of the star positions.

In the observations of Eros itself thirty-two telescopes at twenty-five observatories, situated in England, Belgium, Germany, Italy, Spain, Czechoslovakia, Russia, India, China, Japan, Algeria, South Africa, the United States, Argentina, and Australia, assisted. The writer was in charge of the whole programme. Instructions for the guidance of participating observatories in methods of observation, measurements of the photographs, and reductions of the results were prepared, to ensure uniformity and all possible accuracy. The work of combining and discussing the results from the several thousands of photographs that were obtained has extended over several years and has recently been completed. It is believed that all possible sources of error have been satisfactorily controlled and that the results are accordingly of a high accuracy. The internal consistency of the results is remarkably good: in whatever way the material is divided, rearranged, or grouped, the results are consistent, which confirms the belief that they are free from serious error. The final outcome of this extensive programme of international co-operation is to place the Sun at a distance of 93,005,000 miles, with an uncertainty either way not exceeding 9,000 miles.

One hundred years ago the distance of the Sun was uncertain to one part in twenty; gradually, the uncertainty was narrowed to one part in a hundred; now it has been reduced to one part in a thousand. In the fifth edition of his *Outlines of Astronomy* (1858), SIR JOHN HERSCHEL, referring to a new determination of the Sun's distance, which had brought the Sun nearer by 4,000,000 miles, wrote:

> The superficial reader (one of a class too numerous) may think it strange and discreditable to science to have erred by nearly four millions of miles in estimating the Sun's distance. But such may be reminded that the error in the Sun's parallax, on which the correction turns, corresponds to the apparent breadth of a human hair at 125 ft. or of a sovereign at 8 miles off.

The uncertainty in the newest determination of the Sun's parallax corresponds to the apparent breadth of a human hair at 10 miles or of a halfpenny (for sovereigns are not now available) at 3,250 miles! The goal for which astronomers have so long been striving has at length been reached; the final word has been said on this historic problem for many years to come and the fundamental distance in astronomy has been measured with all the accuracy that is needed.

Agenda

A NEW QUARTERLY

Sir Humphrey Milford announces that he will publish in January 1942 the first number of *Agenda: a Quarterly Journal of Reconstruction*, edited for the London School of Economics and Political Science by Professor G. N. Clark. The purpose of the journal is to make available the results of expert research into the problems of reconstruction on all its sides, domestic and international, social, political, and economic. It will provide clear, fair, and well-informed statements of the facts and problems, written by experts but written both for those who are experts and for those who are not. It will not advocate any policy; but it will be open to articles advocating particular lines of action as well as to objective surveys of facts. The price per number is 6s., annual subscription £1 1s.

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The Epigenotype

C. H. WADDINGTON

The adult characteristics of animals, i.e. their phenotypes, must be studied in order to reach conclusions about the genotypes, i.e. the hereditary constitutions which form the basic subject-matter of genetics. But between genotype and phenotype lies a whole complex of development processes, for which Dr Waddington proposes the name 'epigenotype.' He here describes some of the general characteristics of an epigenotype, with special reference to the fruit-fly *Drosophila melanogaster*.

Of all the branches of biology it is genetics, the science of heredity, which has been most successful in finding a way of analysing an animal into representative units, so that its nature can be indicated by a formula, as we represent a chemical compound by its appropriate symbols. Genetics has been able to do this because it studies animals in their simplest form, namely as fertilized eggs, in which all the complexity of the fully developed animal is implicit but not yet present. But knowledge about the nature of the fertilized egg is not derived directly from an examination of eggs; it is deduced from a consideration of the numbers and kinds of adults into which they develop. Thus genetics has to observe the *phenotypes*, the adult characteristics of animals, in order to reach conclusions about the *genotypes*, the hereditary constitutions which are its basic subject-matter.

For the purposes of a study of inheritance, the relation between phenotypes and genotypes can be left comparatively uninvestigated; we need merely to assume that changes in the genotype produce correlated changes in the adult phenotype, but the mechanism of this correlation need not concern us. Yet this question is, from a wider biological point of view, of crucial importance, since it is the kernel of the whole problem of development. Many geneticists have recognized this and attempted to discover the processes involved in the mechanism by which the genes of the genotype bring about phenotypic effects. The first step in such an enterprise is—or rather should be, since it is often omitted by those with an undue respect for the powers of reason—to describe what can be seen of the developmental processes. For enquiries of this kind, the word 'phenogenetics' was coined by HAECKER [3]. The second and more important part of the task is to discover the causal mechanisms at work, and to relate them as far as possible to what experimental embryology has already revealed of the mechanics of development. We might use the name 'epigenetics' for such studies, thus emphasizing their relation to the concepts, so strongly favourable to the classical theory of epigenesis, which have been reached by the experimental

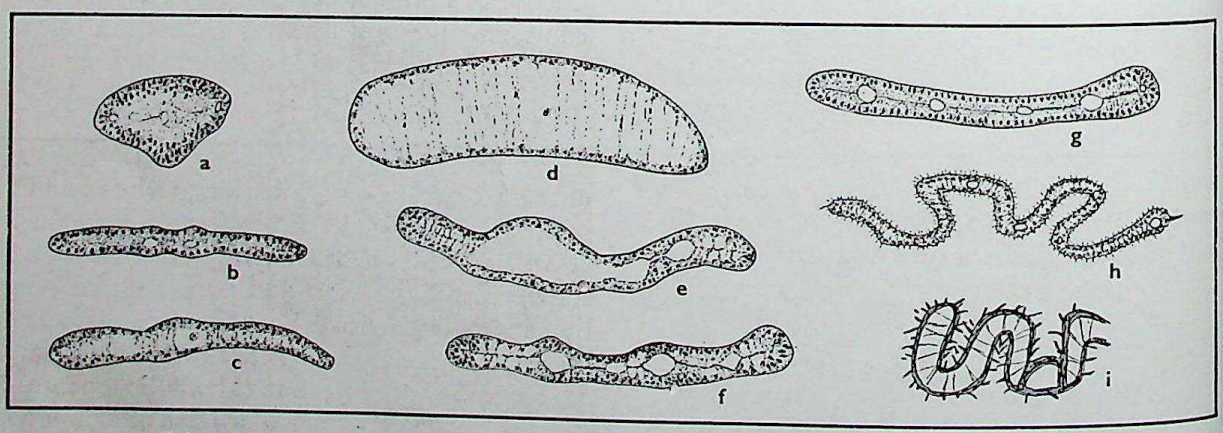

FIGURE 1 – *Diagrammatic drawings of sections of the developing wing in the fruit-fly* Drosophila. *Notice how the wing is at first quite solidly constructed.* (*Figure* 1 b *is of about the same age as figure* 2 A.) *Then it becomes hollow* (*figure* 1 d, *which corresponds to figure* 2 B), *contracts again* (*figures* 1 e, f, g), *and finally becomes folded* (*figures* 1 h, i).

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embryologists. We certainly need to remember that between genotype and phenotype, and connecting them to each other, there lies a whole complex of developmental processes. It is convenient to have a name for this complex: 'epigenotype' seems suitable [5].

We know comparatively little about the general characteristics of an epigenotype. One general feature, however, is that it consists of concatenations of processes linked together in a network, so that a disturbance at an early stage may gradually cause more and more far-reaching abnormalities in many different organs and tissues. Some very beautiful examples of such effects have recently been described by GRÜNEBERG [1], [2], based on mutations in his mouse colony at University College, London. One gene, the 'grey-lethal,' brings about a lack of yellow pigment in the fur, and a failure of the absorption of bone which normally accompanies growth. The latter effect entails a whole host of secondary consequences. Thus the minerals of the body are immobilized in the bones and cannot be used for new growth, so that the teeth are incompletely calcified and unable to masticate solid food. Again, the lack of bone absorption leads to pressure on some nerves, particularly those serving the lower jaw; this presumably gives rise to neuralgic pain, the animals are disinclined to take even liquid nourishment, the starvation affects the thymus gland, and the animals eventually die. Another lethal gene, this time in the rat, brings about even more manifold and at first sight unconnected abnormalities. The first noticeable effect is an abnormality in the development of cartilage, which affects the ribs, and thus the lungs, circulatory organs, and finally the growth-rates of various parts.

Complementary to the study of single genes and the numerous effects which they produce is the study of a single organ and the numerous genes which affect it. Probably the most completely investigated instance is the wing of that favourite genetical object, the fruit-fly *Drosophila melanogaster*. Following preliminary work by AUERBACH, DOBZHANSKY, and GOLDSCHMIDT, I described the developmental actions of some thirty geneloci [6]. It was found that during the first forty-eight hours after the larva enters the pupa, its wings undergo at least fifteen different processes, each of which is affected by some

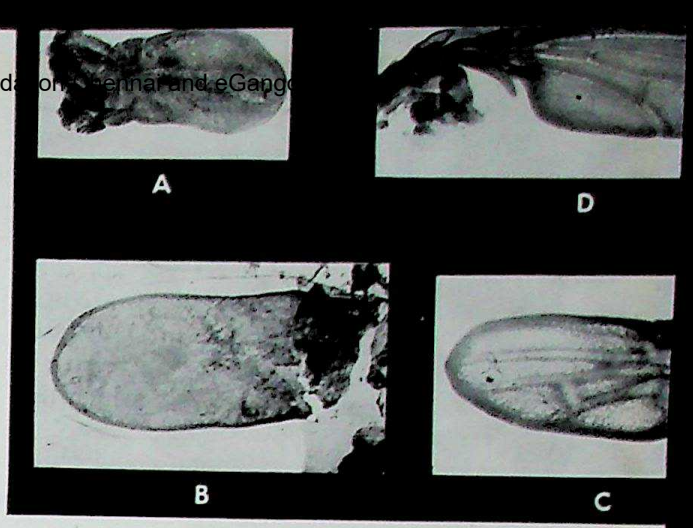
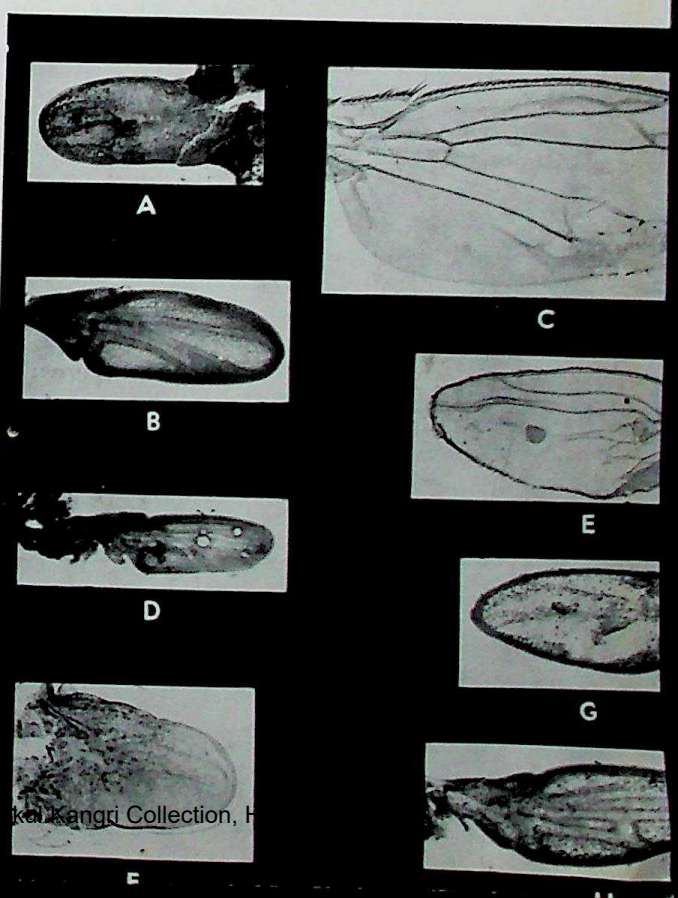


FIGURE 2 – *Four stages in the development of the wing in* Drosop
Figure A *shows the wing shortly after the puparium is formed; in*
wing has become inflated, and its venation is obliterated; in C *and*
contracts again and its final venation appears. Just after the
shown in D, *the wing becomes folded and remains thus until just*
the fly emerges from the pupa.

FIGURE 3 – *Some genetically controlled abnormalities in the cor*
tion-phase of wing-development in Drosophila. *Figures* A, B, *a*
show wings of the mutant race net *in which there is a partial fa*
of contraction, which causes the formation of extra veins in some reg
In figures D *and* E *the failure of contraction is much more complete*
bubbles of fluid are left between the two wing-surfaces, which remo
far apart that in many areas no veins appear (the mutant bloa
In figures F, G, *and* H *the contraction does not fail, but is abnorm*
that a wing of characteristically elongated form is produced (the m
blade *in* D. pseudo-obscura).



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known gene. We have here, in fact, a concrete example of something which has always been obvious in theory, namely that the genotype is in continual and unremitting control of every phase of development. Genes are not interlopers, which intrude from time to time to upset the orderly course of a process which is essentially independent of them; on the contrary, there are no developmental events which they do not regulate and guide.

The alterations in development produced by genetic changes can be used, as the experimental embryologist uses those which he produces by his operating needle, as a means of analysing the causal mechanisms of development. We find, for instance, that if the two sheets of epithelium which build up a *Drosophila* wing fail to come together as they normally do, the cavity left between them may differentiate into a wing-vein instead of into the normal wing surface. Or, again, we find that if the two epithelia are folded together in an abnormal manner, the position of the wing-veins is determined by the upper surface, and impressed by that surface on to the lower one. These deductions from the 'natural experiments' performed by genes can be checked by experiments of the conventional kind; one can make operations on the developing wings, using fine glass needles and the other micro-surgical instruments of experimental embryology. A considerable series of such operations has been made by LEES [4], who was able to confirm, and in some cases to extend, many of the previous deductions.

For this particular organ there remains very little of that gap between genetics and experimental embryology which has been so frequently lamented as one of the main flaws in the structure of biological theory. As would be expected, many of the general principles of experimental embryology reveal themselves again in the epigenetical analysis. For instance, we are familiar with the fact that there are critical periods in development, such as the time of gastrulation at which the primary organizer is active. Similarly we find that in the development of the wing there are certain periods at which many deviations of development, which had previously seemed of only minor importance, suddenly entail radical and far-reaching consequences. To give a concrete example: the wing is essentially a sac the two surfaces of which are, at one period, forced apart by a considerable pressure of the contained body-fluid, which is later withdrawn so that the two epithelia come together again. The process of contraction is a critical one. Slight irregularities in it are responsible for most of the abnormalities in the development of the wing-veins, and minor deviations in the relative positions of the wings and legs may, by impeding the flow of body-fluid, lead to crippling malformations of those organs.

It would take us too far to attempt to discuss in detail the general characteristics of such epigenetic crises as these. We should find ourselves involved with the same highly complex and little-understood series of problems which confront the experimental embryologist; with the problem of structures of various ranges of size, with the differentiation of cells and of tissues, and with the question of whether differentiation is into sharply contrasted alternatives or into a continuously varying range of products. Without attempting to answer any of these questions here, we may be content to point out that the analysis of the effects of genes has now progressed far enough to become merged with experimental embryology. The two methods of analysis whose *rapprochement* has for so long been no more than a pious hope can now actually and in practice come together in an attack on the still unresolved problems of the epigenotype.

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Science in the U.S.S.R.

J. G. CROWTHER

Mr J. G. Crowther has an intimate knowledge of Soviet science and scientists, numbering many of the latter among his personal friends. He is thus particularly well qualified to write with authority upon the personalities, ideas, and achievements of the present-day successors of Lomonosov and Mendeléeff. The freshness and vigour of Russian thought are vividly illustrated by Rehbinder's views that science should consciously aim at creating new industries and not be content with improving old ones.

Since the time of PETER THE GREAT, there has always been notable scientific research in Russia. Peter founded the Academy of Sciences in 1724, after the French model. He and his successors depended a good deal for their academicians on importation from abroad. DANIEL BERNOULLI went to St. Petersburg in that year, and shortly afterwards he was followed by LEONHARD EULER. The Academy from its foundation had a very high standard, but from the nature of its origin it was an exotic intellectual ornament rather than a working organ of the state. In the last ten years especially it has been fundamentally reorganized. The principle of the Academy during the first two centuries of its existence was the appointment of men of ability, the more gifted the better, with handsome salaries and light duties. They were then expected to follow the promptings of their inspiration, and embellish history with new knowledge.

The reorganized Academy has quite a different principle. It is intended to be a powerful organ in the advancement of human life. It has the duty of planning scientific activity in the U.S.S.R. so that it will achieve that end most effectively. The Academy was transferred to Moscow so that its directorate would have closer contact with the Government and its institutes would be in a safer strategical location.

The idea of planning is to develop scientific research in a balanced manner, discover and encourage gifted individuals, and lay down lines of investigation consonant with the main interests of the population. For instance, planning is intended to prevent overlapping, and stampedes into fashionable subjects. It will see that there is a proper division of attention between, say, nuclear physics and radiophysics. The periodical reports on the activities of all laboratories help to prevent good men from being overlooked. The co-ordination of the general lines of research with the main interests of the population taps a strong stream of intellectual energy that might have been dissipated in other directions.

The Physico-Technical Institute directed by PROFESSOR A. F. JOFFE at Leningrad is the most famous of its kind in the U.S.S.R. It is one of the group of institutes attached to the Academy of Sciences, and its activities are a part of the Academy's general plan of research. It was started by Joffe in September 1918 in a few rooms of the old Polytechnic Institute. It was moved in 1923 into a handsome building which had been started in 1914 as a home for retired engineers, but never completed.

As the Institute grew, large blocks of new laboratories and machine-shops were added to it. The original staff consisted of JOFFE, SEMENOV, TCHERNITCHEV, DORFMANN, LUKIRSKY, and FRENKEL. The first aim of the Institute was the training of physicists who could become directors of new institutes and foci of new growths of science in distant parts of the country. As a result of this plan, physical institutes have been founded in Kharkov, Dnepropetrovsk, Tomsk, Sverdlovsk, and Samarkand.

This development sprang from Joffe's institute. He is accordingly admired as the founder of modern physics in the U.S.S.R. His sixtieth birthday was celebrated recently by a fine volume in the Academy of Sciences' *Journal of Physics*, which consisted exclusively of a collection of papers by his former pupils.

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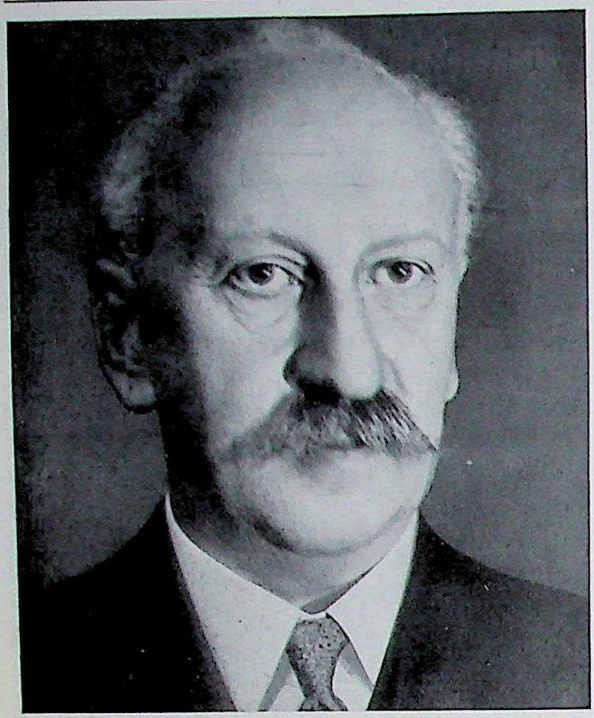

Professor A. F. Joffe.

Joffe's own researches in recent years have been on semi-conductors. He regards these as substances in which electrons have a moderate degree of freedom, in contrast with insulators in which they have very little, and in metals in which they have a great deal. Their study throws light on the mechanism of the breakdown of insulators, because this happens too suddenly for direct investigation. On the other hand, it cannot be deduced from the properties of metals because the flow of current starts too easily. Another line pursued by Joffe is the strength of solids. It is found that the theoretical strength calculated from Born's theory is several hundred times the observed strength. In his researches in this problem, Joffe and his colleagues observed that the tensile strength of a crystal of rock salt was increased 20 times while immersed in hot water. He attributed this to the removal by solution of cracks on the surface of the crystal, which, according to the theory of Griffith, are a major cause of the observed weakness of glass and other solids.

STEPANOW's suggestion that friction between adjacent planes in a crystal under strain leads to a momentary liquefaction has arisen out of Joffe's work, and has helped to explain why a piece of metal may be suddenly twisted and remain strongly set in its new shape. The metal at the surfaces at the planes of slip is momentarily melted, and then sets quickly while the piece is in its new shape.

The recent investigations of S. E. BRESLER and P. A. PHINOGENOV on microscopic steel balls for bearings is a characteristic product of the Joffe school. It follows from a formula for the deformation of spheres first given by Hertz that small balls may be as effective in bearings as large ones, because there are more of them. Accordingly, mass-production methods of making microscopic steel balls were investigated. Soft carbon steel wire was blown through an electric arc into an atmosphere of nitrogen, producing a 'fog' of steel particles in it. When examined, these were found to be shiny and from a few thousandths to a few tenths of a millimetre in diameter. The larger ones were prolate, and deviated by 5 to 10 per cent. from the spherical; while the smaller ones, owing to the more powerful effect of surface tension, were nearly perfect. Balls about $\frac{1}{10}$ mm. in diameter were separated by sieves. When mixed with oil they reduced friction $2\frac{1}{2}$ times as much as oil used alone.

Perhaps the most remarkable achievement that has come from Joffe's institute is SKOBELTZYN's discovery of the very swift particles in cosmic rays. In 1926 he began a study of the velocity of electrons ejected from radioactive sources by photons, with the aid of a Wilson chamber surrounded by a magnetic field. He published photographs in 1927 of particles which shot through the field with such energy that their curvature could not be detected.

The apparatus with which he secured this fundamental observation was of the most provisional character. The timing of the apparatus was controlled by an old Atwood's machine, which seems to be about the only valuable application of this dreary invention on record.

Skobeltzyn obtained several photographs of positrons, but was not lucky enough to be the first to recognize their nature. He has recently been working on the components of the cosmic radiation, and has argued against the theory of Heisenberg and Euler that the spontaneous disintegration of mesotrons is the mechanism responsible for the formation of the electronic component observed in the lower layers of the atmosphere, because, in his opinion, it fails to

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explain the observed divergence between the curves describing the increase in the intensities of the hard and the soft components with height.

One of the most striking figures in Soviet science is N. N. SEMENOV. He is indeed one of the most remarkable men in the world, and is the chief founder of the contemporary theory of chain-reactions. He is a slender, dark-haired man.

SEMENOV and KAPITZA are old friends and fellow-students. In the Leningrad flat of the late MME KAPITZA, the scientist's mother, there used to be a beautiful oil-painting of the pair in discussion over an X-ray tube. It is to be hoped that this historic picture is safe. Semenov started research as a physicist, and studies of the mechanism of the breakdown of insulation, in which a progressive change proceeds through the material, led him to the study of chain-reactions. The classical experiment which accelerated his school on its brilliant career was made by CHARITON and WALTA in 1926. Berthollet had observed in 1797 that phosphorus and oxygen, in spite of their intense attraction for each other at ordinary pressures, do not combine if the pressure of the oxygen exceeds a certain higher limit. Joubert, in 1874, added that the reaction also stops if the pressure falls below a certain lower limit. Chariton and Walta found that if argon were introduced into the vessel, the upper pressure limit was lowered. Semenov showed that the phenomenon could be explained by the theory of chain-reactions. Many more discoveries in the same field have come from his institute. This was founded as a separate laboratory in 1931, an old secondary school building being adapted to the purpose.

Chariton is an old Cavendish student, though his main achievements have been accomplished in chemical physics. He has recently published a characteristic paper on the inability of small charges of explosives to detonate. He made small calibrated glass tubes which were closed at one end, the other end opening out into a funnel about 1 cm. in diameter at the top. These were filled with nitroglycerine, which was left in contact with a priming charge of lead azide at the open end. It was found that if the diameter of the tube was less than 2·08 mm. the detonation did not pass from the wide

Professor Peter Kapitza.

funnel-shaped part of the tube into the narrower cylindrical part. With a 12 per cent. solution of methyl ether in nitroglycerine, the limit rose to about 3·6 mm. One may suppose that, below a certain diameter, the duration of the scattering of the outer part of the charge is less than the duration of the reaction, so that detonation does not occur.

The Semenov school has contributed greatly to the strength of the Soviet Union, besides the advancement of knowledge, because its studies on chain-reactions have provided experts on 'knock' in engines, explosives, and other things of practical importance.

Peter Kapitza is well known to many British scientists. The handsome Institute of Physical Problems has been specially built for him in Moscow. He has recently invented a turbine air-liquefier, in which the initial compression of the air is only 5 atmospheres, instead of 200 atmospheres as in the Linde process. This is achieved by taking the energy out of the gas by making it do work in the turbine, instead of depending on the Joule-Thomson effect, which is of secondary magnitude. As the temperature of the air flowing through the turbine, unlike that of the steam in a steam turbine, is low, the working fluid is much more dense, being about five times that of steam at 250° C.

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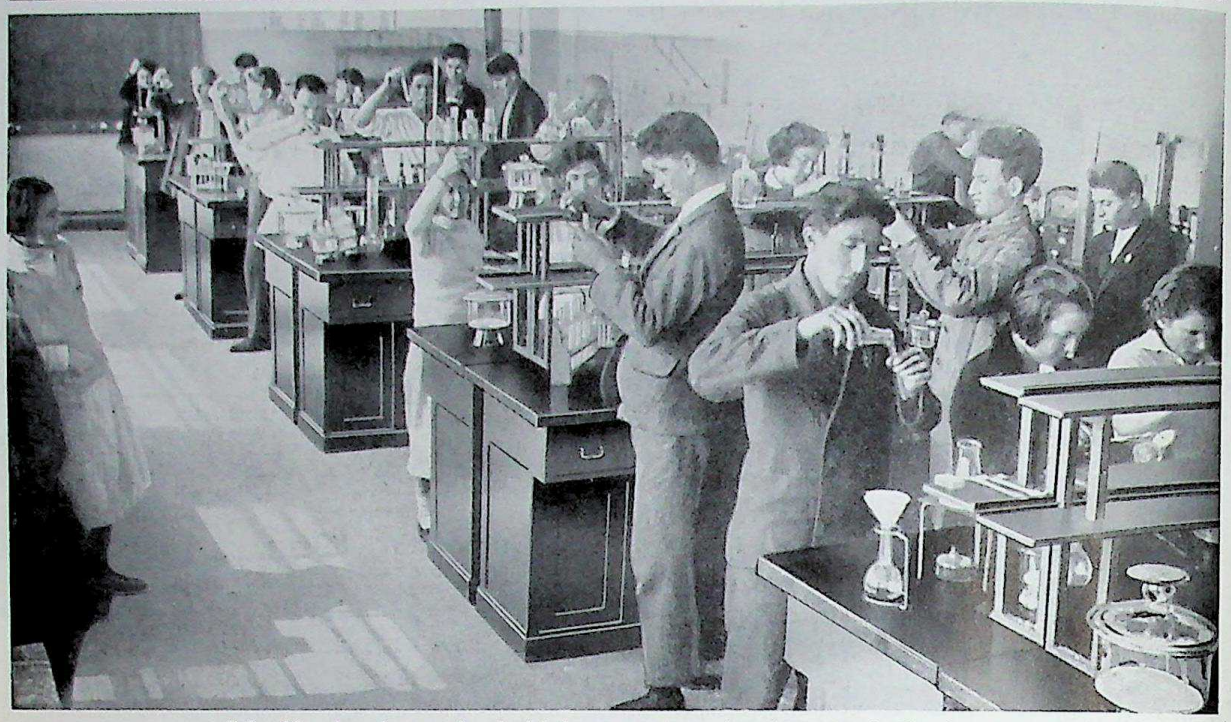

Scientific education: a chemical laboratory at a university centre in Daghestan.

Consequently, the turbine has to be designed to withstand considerable centrifugal forces, like a water-turbine.

Air is compressed by a 50 h.p. compressor, and after passing through water and air coolers is fed at about 7 atmospheres into the turbine. This runs at 40,000 r.p.m., and develops about 4 h.p. The pressure of the air drops 75 per cent. in its passage through the turbine, and if it enters at about — 158° C. it emerges at about — 187° C., the boiling point of oxygen.

The present apparatus produces about 30 kg. of liquid air per hour, and with minor improvements should be as efficient as ordinary high-pressure liquefiers. It is compact, owing to the absence of auxiliary equipment, and it delivers liquid air within the short period of twenty minutes from starting.

Another interesting scientist is P. REHBINDER, who directs research on the chemistry and physics of surfaces in the Physical Institute of the Academy of Sciences in Moscow. He has a burning enthusiasm and energy for research, and original views on the role of science in society. He considers that science should not be the handmaid of industry, but should consciously aim at the creation of new industries. These are vastly more valuable than trifling improvements in conventional manufacturing processes.

Rehbinder's researches include striking investigations on the phenomena of hardness. He has determined the hardness of specimens by deducing the strengths of the molecular fields at their surface from measurements of wettability, and he finds that his results agree with the usual methods of mechanical scratching. His method has the advantage of not damaging the specimen.

He found that thin films are often much harder than solid blocks of the same material. For instance, a thin film of lead on glass may be twice as hard as glass itself, though block glass is thirty times as hard as block lead. In contrast with this, the application of other substances adsorbed by the surface may reduce the hardness.

Rehbinder has recently been examining the effect of the addition of surface-active substances to the mechanical properties of soap-curds. He has added homologues of a number of saturated alcohols, phenol, aniline, etc., to the curds of metallic soaps. He has found that the resistance of the curds to shear is reduced. He believes that the effect is partly analogous to the one he has already described, in which hardness of solids is reduced by adsorbed layers. He thinks that it should be possible to alter the mechanical properties of hard commercial

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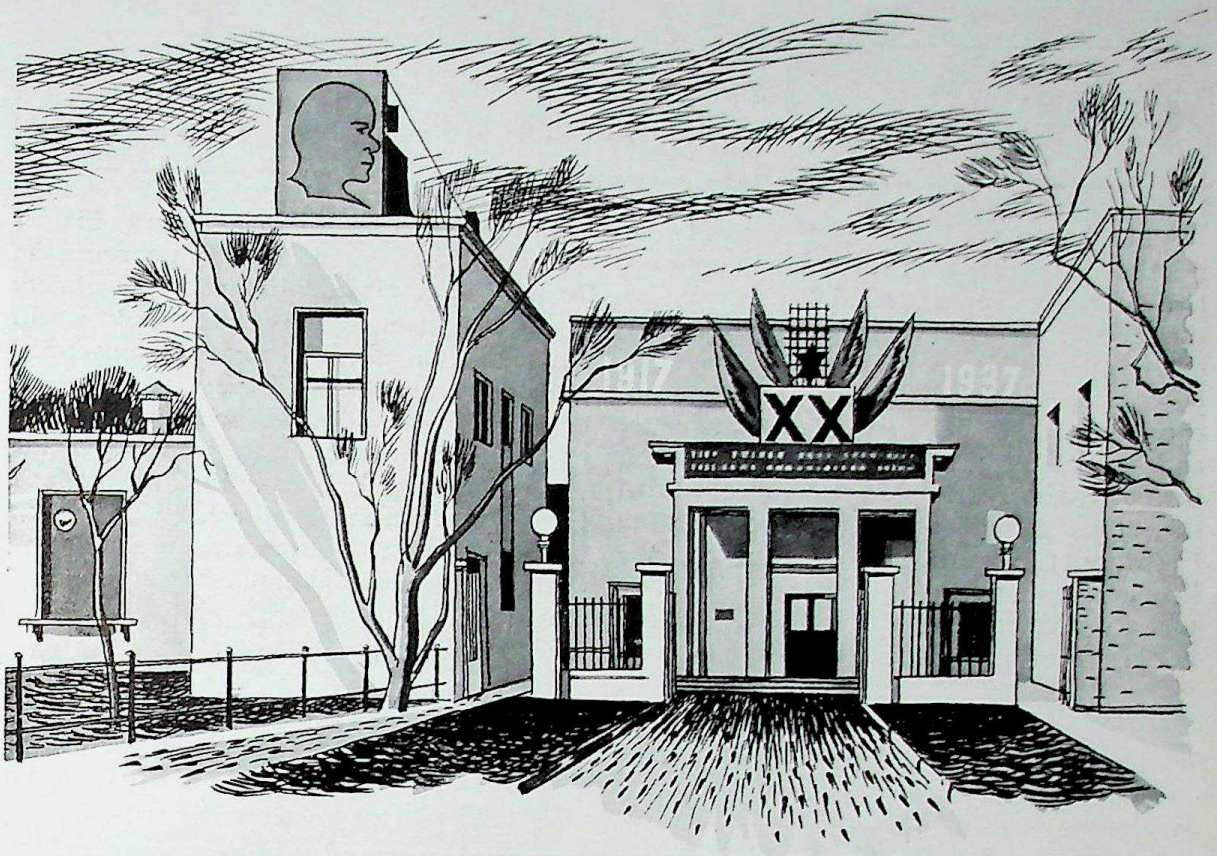

The Institute of Physical Problems, Moscow.

soaps considerably by adding surface-active substances to them during manufacture and use.

Perhaps the most gifted physicist in the U.S.S.R. is L. I. MANDELSTAMM, whose sixtieth birthday, like Joffe's, was recently celebrated by a special volume in the *Journal of Physics* of papers by his pupils. He works in Moscow University and the Physical Institute of the Academy. Mandelstamm is modest, retiring, and self-critical. He does not like lecturing, and is cautious in publication. He discovered, in collaboration with Landsberg, the effect which now bears the name of Raman, in February 1928. While they were checking their results, Raman independently discovered the same effect and promptly published his observations in March 1928. This is only part of Mandelstamm's work. He has created a school of research in non-linear oscillations which is of the highest importance in radiophysics and aerodynamics, and helps to explain the strength of the Soviet Union in these fields.

The theory of non-linear oscillations was founded a century ago in connection with planetary perturbations, and was developed by Poincaré: Mandelstamm began the application of the theory of physical problems about fifteen years ago. Besides leading to improvements in radio circuits, it has inspired the invention of a new type of dynamo. It consists of a condenser which is placed in a circuit containing a self-inductance. The plates of the condenser are shaken by a mechanical motor, so that the distance between them is always changing. This varies the capacity of the condenser and produces a current in the circuit whose period is one half that of the mechanical oscillator. Thus the energy of the mechanical oscillator is converted into a high-voltage electric current.

Such are a few of the Soviet scientists and their researches. There are hundreds of others, in very different branches of science. They are an example of the quality and energy of the scientific workers in the U.S.S.R.

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British scientific genius

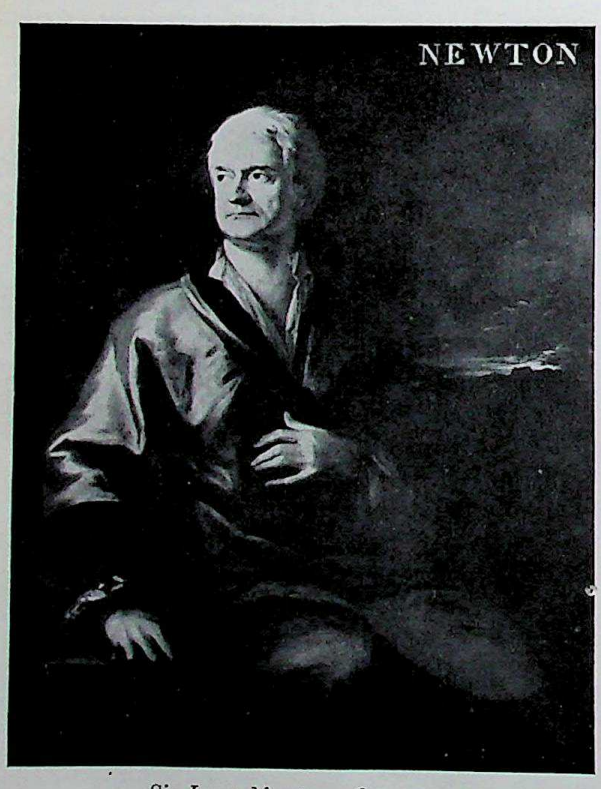
An illustrated review of *British Scientists*[1], by Sir Richard Gregory, Bt., F.R.S., a new volume in the series *Britain in Pictures*, published by William Collins of London.

Amid the strife of faction or the din of battle it is not always easy to preserve a right perspective of events. Few educated Parisians under the Terror would have regarded Lavoisier's overthrow of phlogiston as more pregnant of effect upon the future of civilization than the execution of Louis XVI and Marie Antoinette, and no contemporary could have justly gauged the relative importance of two events of 1812—the retreat of Napoleon from Moscow and the discovery of iodine by Bernard Courtois. We live in even more disturbed and disturbing times, so that it is well for us to take stock of our judgments and examine them with a poised objectivity.

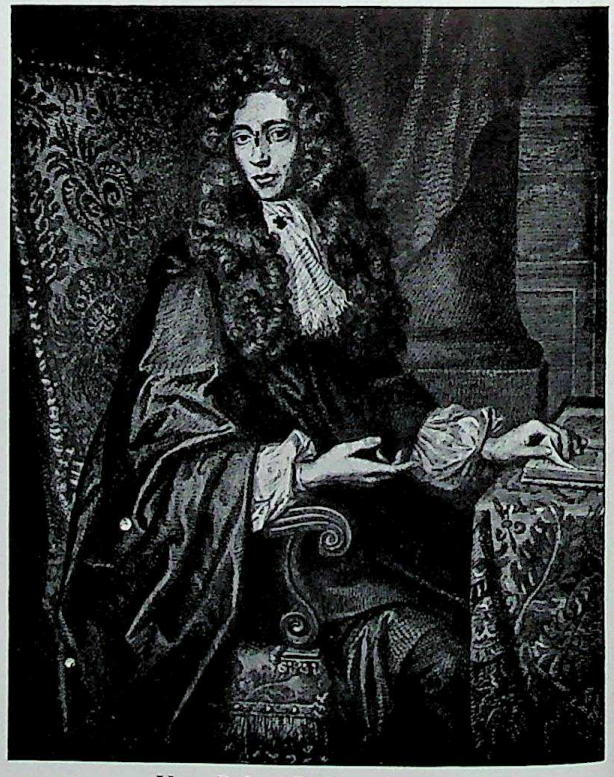
If we do this, we can hardly avoid the conclusion that, though scientific discoveries have often been—and are still being—put to shameful use, science has immeasurably improved the lot of man and possesses unlimited potentiality for further good in the future. Advance in civilization, indeed, is advance in science; and when, as at present, civilization is threatened, the threat is implied no less to science. This is made clear, if illustration were needed, by the wholesale reduction in numbers of students and teaching staff effected by the Nazis in German university laboratories, scientific institutes, and other educational establishments where science is taught.

Yet, though civilization is the gift of scientists to mankind, they have often little honour in their own or any other country. The Englishman to whom the names of Drake, Hawkins, Frobisher, Cromwell, Nelson, Wellington, Haig, Jellicoe, and Beatty are familiar and celebrated

[1]Pp. 48, with 12 plates in colour and 19 illustrations in black and white. William Collins, London. 1941. 3s. 6d.



Sir Isaac Newton, 1642-1717.
Oil painting attributed to Sir James Thornhill.



Hon. Robert Boyle, 1627-91.
Engraving by B. Baron after the painting by T. Kerseboom.
By courtesy of the Institute of Chemistry.

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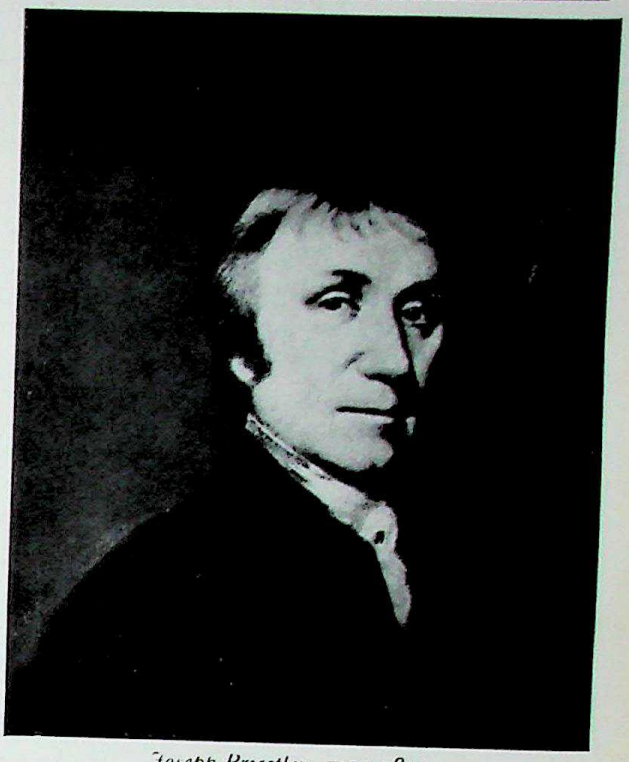
Sir Humphry Davy, 1778-1829.
Oil painting by Sir Thomas Lawrence.
By courtesy of the Royal Society.



Joseph Priestley, 1733-1804.
Chalk drawing by Ellen Sharples.
By courtesy of the National Portrait Gallery.

Michael Faraday, 1791-1867.
Oil painting by A. Blakeley.
By courtesy of the Royal Society.

James Clerk Maxwell, 1831-79.
Engraving by G. J. Stodart.
By courtesy of the Cavendish Laboratory.

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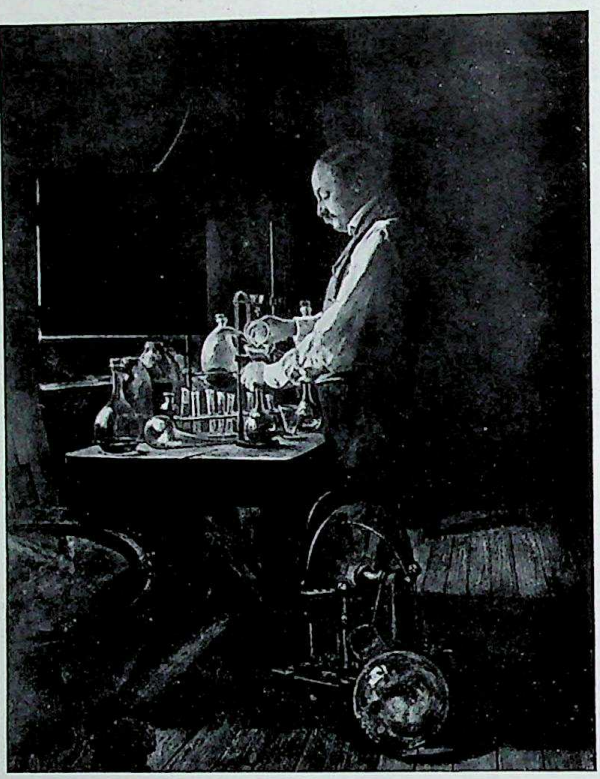
would usually find it difficult to recall an equal number of his country's men of science. It is, nevertheless, indisputably true that these soldiers and sailors, great as they were, signify less in the grand progress of humanity than Boyle, Newton, Cavendish, Dalton, Davy, Faraday, Darwin, Huxley, and J. J. Thomson.

In his small but delightful book *British Scientists* Sir Richard Gregory sets out to tell the public something of their scientific countrymen from the days of Roger Bacon to the early years of the present century. He rightly points out that, though science is an international study, 'British scientists have taken a leading part' in its development, 'and their works occupy a prominent place in the records of achievement of most branches of modern science. Their contributions are particularly distinguished by originality of conception in combination with experimental inquiry. It is scarcely too much to say that British scientific genius is prominently displayed in the discovery of the most significant and universal principles in Nature, as well as in the field of pioneer mechanical invention.'



Lord Rayleigh, 1842-1919.
Oil painting by Sir Philip Burne-Jones.

Sir Richard begins his story with Roger Bacon—a very appropriate starting-point, since this medieval friar was one of the first to insist upon the value of experiment in scientific investigation. The experimental method seems so obvious to us today that we are inclined to regard it as having always been so; in actual fact it was of very slow growth and did not reach full maturity until the seventeenth century. Before the time of Boyle (1627-91), the most celebrated English disciple of Bacon was William Gilbert, who applied the experimental method in investigating the properties of magnets, invented the word electricity, and was one of the earliest advocates in England of the views of Copernicus. With Newton (1642-1717), British science burst into full efflorescence, entering upon a period of brilliance that has continued until the present day and shows no signs of diminishing intensity but rather the contrary.

A powerful factor in the advance of science is represented by such bodies and foci as the Royal Society and the Royal Institution, and Sir Richard gives outlines of their history and work. He also has sections on such topics as the steam engine, the locomotive, the dynamo and the turbine, all of which are British inventions; on electromagnetic waves, where the pioneer work was carried out by Faraday and Clerk Maxwell; on the structure of atoms, another field in which the fundamental researches were made in Great Britain; and on several further aspects of scientific progress due largely to British scientists. Even the most indifferent layman should be stirred to pride in British scientific genius when he reads these pages—few in number, but each recording some discovery of vital importance to human welfare.

The admirable quality of the text is equalled by the very fine collection of portraits, upon which both Sir Richard and his publishers are to be congratulated—the author for his skill in selection and the publishers for the excellent way in which the portraits are reproduced. By kind permission of Messrs. Collins, several of the portraits are given again here; but it should be pointed out that, in the book itself, no fewer than twelve of the plates are in colour.

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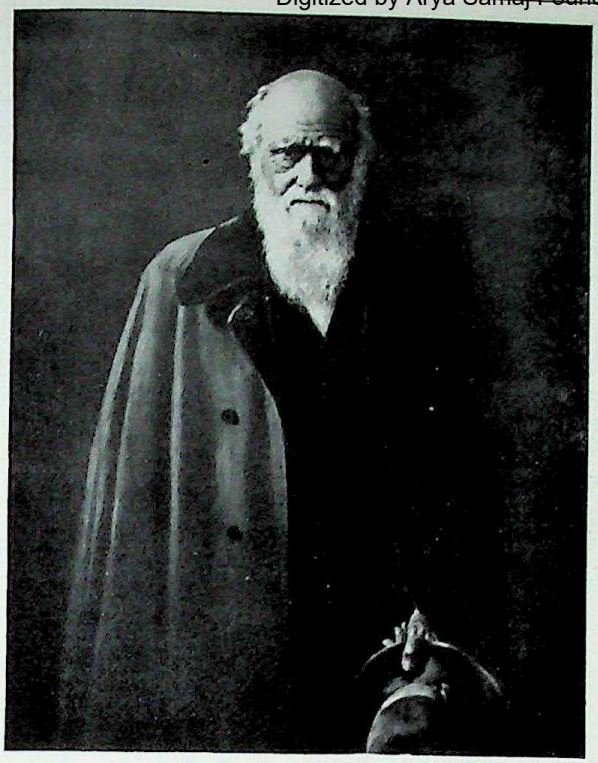
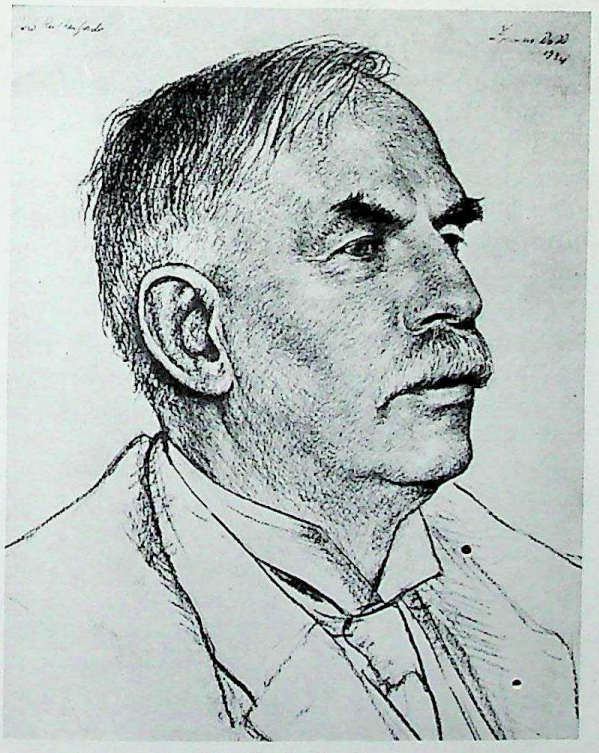


Charles Darwin, 1809-82.
Oil painting by John Collier.

Sir Joseph Thomson, 1856-1940.
Oil painting by Arthur Hacker.



Lord Rutherford, 1871-1937.
Drawing by Francis Dodd.
By courtesy of the Trustees of the Fitzwilliam Museum.

Sir William Bragg, 1862- 1942
Oil painting by Sir William Nicholson.
By courtesy of the Artist and the Royal Institution.

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The manufacture and use of vitamins

A. L. BACHARACH

The subject of vitamins is one of those scientific topics which from time to time attract popular attention and form 'news.' Unfortunately the average British journalist seems to imagine that work on vitamins has been carried out in 'every country but his own.' Mr Bacharach, in reviewing the vitamin problem, shows that Britain has played a leading part in its solution.

Much has been done in Great Britain—and is still being done—in the manufacture of vitamin concentrates and pure vitamins and in presenting them to the public, either by way of 'fortifying' foods or in medicinal form.

The discovery that Vitamin D, which prevents rickets in young children and an analogous disease of the bones in adults, could be produced by the action of ultra-violet rays on certain fats was made almost simultaneously by STEENBOCK and the late ALFRED HESS in the United States. It was not long before the actual compound concerned, the pro-vitamin as it is called, was identified; in this work British scientists and a German group working at Göttingen also played a dominating part. The actual isolation of pure crystalline calciferol, the name given to the vitamin produced by irradiating vegetable fats or their pro-vitamin, was in fact accomplished almost simultaneously in 1931 and 1932 by a group of workers at the National Institute for Medical Research and by PROFESSOR WINDAUS' team, and it is pleasant to recall that a considerable interchange of information took place between these 'rival' groups. Crude concentrates of Vitamin D had already been made available to the public by at least two firms of British manufacturers. It must be emphasized that the term 'crude' is used in a relative sense only; even these crude concentrates had an extremely high antirachitic activity, many hundreds of times that of the best cod-liver oil. However, within two years of the isolation of calciferol, oil solutions, tablets and other medical preparations of the pure crystalline vitamin were being manufactured and marketed by at least four firms in this country. To this day, as far as is known, England and Germany are the only two countries in the world where the manufacture of calciferol has reached a relatively large scale.

Meanwhile, the margarine manufacturers had been seeking methods of improving a food on which nutritional experts had been inclined to look somewhat coldly. The chief respect in which margarine was inferior to butter, apart from palatability, was in its complete freedom from both Vitamin D and the equally important Vitamin A. Certain brands of margarine were fortified with concentrates of both these vitamins; as soon as calciferol became available on a commercial scale, the margarine manufacturers replaced the cruder concentrate with this pure crystalline vitamin and increased the number of brands to which it was added. The compulsory 'vitaminization' of margarine that has taken place since the war has merely been an extension to the whole margarine output of a practice already in partial operation in this country and many countries abroad. It may be added that although 1 gram of calciferol is sufficient to fortify 40 tons of margarine, the requirements for calciferol (and for the necessary quantity of Vitamin A concentrates) reach very high levels. Without access to figures that are not easily available outside Government Departments, it is not possible closely to compute the quantities concerned. If, however, we assume that 4 oz. of vitaminized margarine are eaten every week by every member of the population, which can be taken as 40,000,000 (and

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this is probably a considerable underestimate on both points), it can easily be calculated that the weekly requirements of calciferol are 120 grams, i.e. approximately 1 lb. a month. To this must be added production for export, as well as for use in medicinal products here and abroad.

Those who can recall the excitement with which the first few almost microscopic crystals of calciferol were inspected by enthusiastic chemists, no longer than ten years ago, are in the best position to realize what an achievement this represents. The manufacture of calciferol is by no means a simple or straightforward operation, but one that involves scrupulous care and high manufacturing skill at every stage. Furthermore, the fortification of the margarine has itself to be rigorously controlled and finally confirmed by difficult and complicated biological tests.

A similar story could be told of the gradual improvement in preparing Vitamin A concentrates. These, unlike calciferol, are not made artificially by the conversion of an inactive provitamin into the required compound, but are prepared by the concentration of the vitamin from rich natural sources, in particular fish-liver oils. Hundreds of thousands of gallons of these oils have been through the British manufacturing plants under the control of British chemists, who have succeeded in preparing concentrates of such potency that they can be incorporated in margarine without in any way affecting its taste or odour. To this result, again, the work of scientists in many countries has contributed, that of British chemists, biochemists, physical chemists, organic chemists, and others being by no means least.

It is not possible here to consider, even briefly, the similar history that lies behind the present-day manufacture of other vitamins. Vitamin C (ascorbic acid), necessary for the prevention of scurvy; Vitamin B_1 (aneurin), the anti-beriberi vitamin; nicotinic acid, the pellagra-preventing factor; Vitamin E (tocopherol), an essential for normal reproduction; and also a compound closely related to Vitamin K and identical in physiological properties, necessary for the normal clotting of blood—all these have been isolated from natural sources, have had their chemical nature precisely determined, have been synthesized in the laboratory and are today being made in British factories.

It is perhaps desirable here to say a few words about the oft-recurring controversy as to the superiority of 'natural' over 'artificial' vitamins. This controversy does not exist for the chemist, who recognizes each vitamin as a separate chemical individual, having properties that depend upon its chemical structure and not on its origin or method of manufacture. Nevertheless, many people, unfortunately including some physicians, still seem to have a curious semi-mystical belief in 'nature' and her products. Why something made by man, himself a product of nature, should be held to be unnatural, is a little difficult to understand, but it is not necessary to appeal to the criteria of logic or to trespass in the dangerous realms of metaphysics in order to be clear on this matter. It has arisen in the past, long before the very existence of vitamins was suspected, and it will doubtless arise again. When salicylic acid was first made from coal-tar, there were many who thought that it did not, and could not, have the virtues of salicylic acid prepared from the wintergreen plant. Today no doctor dreams of insisting upon 'natural' salicylic acid or aspirin made from natural salicylic acid. By the same token, the Vitamin B_1 produced in ever-increasing quantities, both for medicinal use and for the fortification of white flour, is identical in composition and properties with the minute amounts that were first isolated from yeast, wheat-germ, or rice polishings in laboratories, in several parts of the world.

The confusion, however, has a partial explanation, though little justification, in the nature of deficiency diseases. These generally arise in populations living at a very low level of subsistence, and it happens more frequently than not that a deficiency disease is due to shortage or absence of several factors from the diet. When these deficiency diseases are cured by natural products, by food-substances like liver or yeast or orange-juice, for example, it is possible—indeed probable—that more than one deficiency is being relieved by the treatment. If now the physician has laid undue emphasis on a single deficiency, and proceeds to administer one vitamin only, he may not obtain the same success as is possible with the 'natural' product. But this is not because the natural vitamin differs from the artificial one. It would make not the slightest difference to

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his result if he used Vitamin C laboriously isolated from lemon-juice or black-currants, or Vitamin C made in the factory by a series of complex and beautiful reactions from glucose as the starting material. Either he would obtain a cure with the vitamin, whatever its origin, or he would not.

This brings one immediately to the question of vitamin 'pills,' a somewhat unworthy description of the elegant tablets and capsules now available to the medical profession and the general public in innumerable pharmacies throughout this and every other country. On the matter of multivitamin treatment, there are different schools of thought. Most British manufacturers have preferred to concentrate on the preparation of products containing one, or at the most two, vitamins in known and specific quantities, and to leave the medical practitioner to decide if more than one of these products should be administered to a particular patient. Such a policy has the advantage of giving flexibility of dosage, to suit different conditions, and in the opinion of many people it is the desirable policy for peace-time. It is unfortunately true that the price of such products, because of the large amount of research and skill that has gone into their production, is such as to put them out of reach of the majority of the population, even in relatively wealthy countries, except when there is actual illness and they are to be taken specifically as medicine. In ordinary times, people who could most benefit from such products as regular supplements to their food are the very people who can least afford them. Alternatively, to market such products at a price within the reach of the less fortunately circumstanced would be possible only if they included such relatively small amounts of the different vitamins as to make them practically valueless for the purpose intended.

Conditions in war-time have somewhat altered the picture. There is more to be said today for encouraging people to supplement their diets with adequate amounts of concentrated or pure vitamins than there was even in peace-time, but the economic problem remains. Such a practice could, in fact, be widespread only if the products were made available through suitable Governmental action, and even then considerable caution would need to be exercised in the claims made for the practice. At the present time we have much reasonably accurate knowledge about human requirements for most of those vitamins that have been made available in pure form and in large quantities. But the advance of knowledge and research, still continuing in this country, makes it highly probable that other vitamins yet remain to be isolated, isolation doubtless to be followed in due course by establishment of their chemical constitution and of methods of synthesizing them. Indeed, we know today of three or four substances, occurring in some foods and essential for the health of certain species of animals, that are very likely also essential to the health of man; they have, in fact, been synthesized, but ignorance of human requirements for these compounds has not yet made it worth while to begin manufacturing them on an extensive scale.

If, however, these known substances, and others as yet unknown, are essential to health, it follows that no multivitamin 'pill' that can at present be devised will adequately replace a mixed all-round diet of a kind known to be necessary for optimum nutrition. The widespread distribution of multivitamin products could certainly prevent the occurrence of known deficiency diseases—scurvy, rickets, beriberi, pellagra—as well as night-blindness and other manifestations of Vitamin A deficiency. It might, therefore, be a measure of far-seeing intelligence to make available to every man, woman, and child in Great Britain a product containing a reasonably adequate daily dose of Vitamins A, B_1, C, and D and nicotinic acid. But this could be done without risk only if at the same time propaganda, education, and the necessary practical steps for improving dietary habits, even on the basis of the foods available under war conditions, were maintained and intensified.

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Prospects for soil conservation

G. V. JACKS

During the last few years, the world has awoken to the dangers threatening it from soil exhaustion caused by short-sighted methods of agriculture. Much has been written on the subject, and at least one country, the United States, has taken active steps to prevent the impending catastrophe. But in many parts of the British Empire and elsewhere the economic incentive to exploit the soil remains too great to be resisted, so that a problem of great urgency awaits solution. Mr G. V. Jacks, Deputy Director of the Imperial Bureau of Soil Science at the world-famed Rothamsted Experimental Agricultural Station, here describes the whole matter with a lucidity and a freedom from technicalities that will make it clear to every reader.

During the last century, wherever new land has been opened up for settlement, there have been practised kinds of agriculture which have resulted in a depletion of the natural fertility of the soil. Soil-depleting agriculture is almost invariably the rule when land is first settled, and there is nothing particularly blameworthy about this latest, world-wide appearance of it. But a remarkable feature of recent settlements has been the rapidity with which symptoms of soil exhaustion have appeared after a country has been opened up. The first symptoms are falling yields, which nobody bothers much about, because they are expected. A later and quite unexpected phase of soil exhaustion has been not a further gradual diminution of yield, but the more or less complete disappearance of the soil itself. It is practically impossible to reduce the crop-producing power of soil to zero however exhaustively it is cultivated, but it has been found that long before complete exhaustion is approached, the soil loses its capacity for remaining in place. A fertile soil, wherever it is formed, has many of the properties of a sponge—it can absorb quantities of water, and possesses considerable internal cohesion. An infertile or exhausted soil loses this water-absorbing capacity and cohesiveness, and breaks down to a mass of separate particles, in which condition it is very readily washed away by water or blown away by wind.

In this way, as a result of the depletion of a mere fraction of the total soil fertility, enormous areas, mainly in North America, Africa, and Australia, have been denuded of soil and are now to all intents and purposes barren wastes. The current wastage of land through this so-called soil erosion is not immediately serious for the world as a whole, since there is still plenty of good land for everybody, but it is becoming serious in certain countries, notably the United States and territories in South and East Africa. It was stated a few years ago that at the then rate of erosion the United States would be incapable of organized existence by the end of the century. For much of Africa, where erosion is a more rapid process, the end of the century would be an optimistically distant date for the end of human dominion over the land.

Summary figures of a national survey made in the United States in 1934 illustrate the extent of the damage done by soil erosion, mainly within the last forty years. Of the total land area 14 per cent. had lost three quarters to all of the soil, 42 per cent. had lost one quarter to three quarters of the soil, and 30 per cent. (much of it unsuitable for agriculture) was uneroded. Apart from the loss of productive soil, incalculable damage has been done by chronic flooding of the main rivers, progressive desiccation of the land, and the profound disturbances to the normal regime of ground waters that are produced by the disappearance of the absorbent surface soil and adversely affect agriculture even where no erosion has occurred. The process of erosion, once started, proceeds under its own acceleration in ever-widening circles. It works insidiously, striking

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at the base of social existence while leaving the main superstructure of society untouched. For this reason it never has been, and probably never will be, taken in hand by the community as a whole until it has reached an advanced stage at which the threat to the superstructure becomes apparent.

The cause of soil erosion is often given as the destruction of the natural vegetation which normally affords the soil adequate protection from the erosive action of rain and wind. This is correct up to a point, but there is no reason why the destruction of the natural vegetation, whether forest or grassland, should necessarily be harmful. All agriculture involves such destruction, and it stands to reason that no permanent agriculture is possible where the soil is progressively deteriorating. The real cause of erosion is the practice of an agriculture which does not take full account of the natural limitations of the environment and causes soil exhaustion, which is the invariable precursor of soil erosion. Soil in a high state of fertility rarely erodes, even when stripped of vegetation, and the only certain cure for soil erosion is to utilize the land in a manner which maintains, and preferably increases, its fertility. Such a type of land utilization is general in the highly farmed countries of Western Europe, where, despite prolonged and intensive agriculture, the soils are probably now capable of greater and more sustained production than at any previous time. The agriculture of the Middle Ages was, like the present-day agriculture of much of the New World, soil-exhausting, and might ultimately have caused widespread erosion had it not been put on an entirely new basis by the agricultural revolutions of the seventeenth and eighteenth centuries. These resulted in a type of agriculture that, so far as the maintenance of soil fertility was concerned, made the optimal use of the natural qualities of the environment.

In the eroding countries of the New World a comparable harmony between agriculture and the environment does not exist; erosion is, indeed, the most common physical symptom of an absence of such harmony. In these countries the evolution of agriculture has been governed by opportunism—by the potentialities rather than by the limitations of the environment. The latter, however, are now making themselves felt. Nature imposes her own harsh discipline on those—whether man, animal or plant—who cannot or will not play their allotted part in preserving the biotic equilibrium which assures the continuing fertility of the earth. Elimination is the invariable rule in such cases, and soil erosion is a very effective way of eliminating man. Agriculture must either develop into a process that increases the fertility of the soil, or cease altogether. The factors, chief among which is the climate, that determine how the soil must be cultivated so as to increase its fertility are still largely outside human control.

On the other hand, the factor which determines how the land actually is utilized is primarily economic. In general, men will always cultivate the land in the way that gives them the greatest economic advantage, and soil-exhausting agriculture, which implies drawing on the existing fertility reserves, tends to be easier and more immediately profitable than soil-conserving agriculture, which implies investing something in the land to pay a dividend at a later date. Consequently, although the measures required to stop erosion and build up soil fertility are simple and understood everywhere, they are not applied on a scale commensurate with the task unless and until the economic conditions of a country make it more profitable to conserve than to exhaust the soil. The first essential step in the soil-conserving agricultural revolution in Britain—the enclosure and pasturing of exhausted arable land—was promoted by the prosperity of the wool trade and the contemporary depression of the grain trade. In recent years one country—the United States—has apparently turned the corner from soil-exhausting to soil-conserving agriculture, not from a recognition of the fatal consequences of continuing soil erosion, but as a result of the disappearance of the export market for soil-exhausting crops. The Agricultural Adjustment Administration was set up to reduce the acreage of these unsaleable crops; it has survived many vicissitudes to become a powerful agent in encouraging the cultivation, in their place, of soil-conserving crops. American economy is developing along lines which are making it more profitable to make than to destroy soil fertility. Provided future developments are in the same direction, the problem of soil erosion will solve itself.

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These developments are towards a more self-sufficient economy than has prevailed hitherto. As agriculture becomes self-sufficient, the limitations of the natural environment assume a much greater importance than they possess in a period of expansion. The countryside begins to take on an appearance dictated by the qualities of the land, and human society a form which harmonizes with the environment. Permanent agriculture is established and civilization has a chance to develop on a secure foundation. Already we can trace in the United States the emergence of new cultural patterns representing the landscapes of permanent, soil-conserving agriculture. Associated with these patterns there is emerging also a new form of society that is based on the community as the ultimate social unit and rejects the 'rugged individualism' which was such a marked feature of the pioneering era. It has been proved beyond doubt that the individual, working by and for himself and in open competition with his fellows, is incapable of preserving the fertility of the prairie environment; sooner or later he must destroy the soil in the struggle to maintain his position in society, whereas a co-operating community of farmers acts spontaneously in such a way as to preserve its social base, the land. Unstinted co-operation between occupiers of land is now recognized as so vital to the success of any scheme for soil conservation that the Federal authorities refuse their essential assistance unless co-operation is assured. What co-operation means at the present time—a very embryonic stage in the evolution of permanent agriculture—is that while the owner retains full legal title to his land the community of which he is a member decides how he shall utilize it; and unless the community decides that the land shall be worked so as to conserve its fertility, the very existence of the community itself is threatened.

The necessary requisites for the accomplishment of soil conservation in an eroding region are thus, firstly, an economic system under which it is more profitable to make than to destroy soil fertility, and secondly and complementarily, a form of society that can work the economic system. Given these—they are complex functions of the environment—permanent, soil-conserving agriculture follows automatically. There is nothing particularly difficult about the technique of permanent agriculture, but the conditions which make its application generally acceptable must obtain. In Britain they have obtained for so long that soil conservation has become the primary concern of agriculture, and not all the outcry for super-efficient farming can shift the deeply rooted instinct of the community to preserve the soil intact. In the United States favourable conditions, first created by the world-wide economic depression, are just beginning to appear. Thanks partly to the neglect of British agriculture and partly to their financial indebtedness to the Mother Country, the main agricultural regions of the British Empire retained their overseas market after the agricultural depression, and have continued to export large quantities of the produce and fertility of the soil. The economic incentive to exploit the soil has been too great to be resisted.

It is doubtful indeed whether agriculture can ever become conservative so long as the farmer is concerned with adapting his practices more to the requirements of a foreign market than to the limitations on land utilization imposed by Nature. In other words, a large measure of self-sufficiency is indispensable to the establishment of permanent agriculture. This is what one would expect on theoretical grounds, and it is fully borne out by recent experience. The United States owes the salvation of its soil to the disastrous breakdown of international trade; other eroding countries may survive to thank the grim economic aftermath of the war for affording the opportunity to reorganize their agriculture on a stable and enduring foundation. It is at least certain that a heavy price is owing for soil exhaustion, but the sooner payment is enforced the less onerous it will be.

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Vignette of a master and his masterpiece

JOHN READ

James Young, founder of the Scottish shale oil industry, formed an outstanding collection of rare and early books and manuscripts on alchemy and chemistry; and in John Ferguson he found an excellent and erudite cataloguer.

It is a sad reflection to students of historical science that Ferguson's *Bibliotheca Chemica* is unknown, even by name, to the great majority of chemists and chemical students of the present day. The two handsome volumes are to be seen in all our great libraries, but their pages are too often uncut. Accomplished chemists of the present generation have been known to ask wonderingly: 'What *is* this *Bibliotheca Chemica* you mentioned, and who *was* Ferguson?'

James Young.

Bibliotheca Chemica is the great master-work of alchemical bibliography, and JOHN FERGUSON was in the first flight of historians of science. *Bibliotheca Chemica*, it is true, bears the somewhat misleading sub-title: 'A catalogue of the alchemical, chemical and pharmaceutical books in the collection of the late James Young of Kelly and Durris, Esq., LL.D., F.R.S., F.R.S.E.' Far from being a mere catalogue, this monumental work, issued at Glasgow in 1906 in two closely printed volumes containing more than a thousand quarto pages, is the most valuable of all publications dealing with the bibliography, the history, and the leading figures of alchemy and early chemistry. It consists of an alphabetical arrangement, under authors' names and titles, of the extensive Young collection, with bibliographical details of each work, biographical notices of the writers, and exhaustive lists of references in chronological sequence. Its scope and accuracy are a continual source of wonderment to all who have had occasion to gain an intimate acquaintance with its contents. Not the least remarkable fact about a work so esoteric in character is its close connection with modern chemical industry.

Dr James Young (1811–83) studied chemistry at Anderson's College, Glasgow, under the famous Thomas Graham, and later founded the shale oil industry in Scotland. About 1850, following the example of his friend, Dr Angus Smith, James Young began to collect works of interest in the history of alchemy and chemistry. In this pursuit he was aided materially by Dr John Ferguson (1837–1916), Professor of Chemistry in the University of Glasgow from 1874 to 1915. The resulting collection was eventually bequeathed to the Chair of Technical Chemistry which Young had founded in Anderson's College; this institution developed into the Royal Technical College, where the Young Collection is now kept. 'The founder of a great industry, . . . engrossed in business transactions,' wrote Ferguson, 'was hardly the person whom one would have expected to undertake the formation of a library of old, neglected, and out-of-the-way books on the practically extinct topic of alchemy; yet Dr Young did this because he perceived that as alchemy happened to be one of the phases which chemistry formerly presented, a survey of it is indispensable for completing the history of the whole science.'

Altogether, Young collected some 1,350 or 1,400 separate items, including many of the

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'omnibus' volumes, such as Manget's *Bibliotheca*, which are so characteristic of alchemical literature. As Ferguson pointed out, many of the books represented in the collection had become almost extinct by the end of the nineteenth century. 'It is fortunate,' he wrote, 'that some of these exceedingly rare treatises in English were secured before it was too late.' The collection is particularly rich in German alchemical writings of the seventeenth and eighteenth centuries.

The Ferguson Collection, which is in some respects still more extensive than the Young Collection, is preserved in the Library of the University of Glasgow. Professor John Ferguson was no less successful as a book-hunter than as a bibliographer: 'he, single-handed, challenged competition with institutions like the British Museum and the Bibliothèque Nationale,' remarks Professor T. S. Patterson, who mentions, as a specific example, that of Beguin's *Tyrocinium Chymicum;* in its various forms the Bodleian Library and the Young Collection have eight copies each, the British Museum thirteen copies, the Bibliothèque Nationale seventeen copies, and the Ferguson Collection no fewer than thirty-one copies, representing twenty-three editions.

John Ferguson.

The same writer has given some interesting glimpses of Ferguson's personality. Like other bibliophiles, he was very reluctant to destroy any kind of printed matter, and his literary accumulations threatened to monopolize his house. Publications expelled him from his study and overflowed into his dining-room, obliging him to use his dining-room table for the examination and annotation of his latest acquisitions in his neat and delicate handwriting. The literary inundation first reached

> the sofa which stood between the two windows, and when that article of furniture had become hopeless as a place of rest even for more literature . . . began to accumulate on the front of a large bookcase, . . . then spread to the corner of the room just opposite the door, then under the old-fashioned pedestal sideboard, taking in its passage an arm-chair, . . . and at the end had reached to the corner of the hearth.

Ferguson's senses of sight, hearing, smell, and taste remained most delicate to the last; he had a peculiar discrimination not only in scents but also in wines. Beyond walking, his only exercise was dancing. His writings indicate that he had a dry and somewhat grim sense of humour.

In the short introduction to his *magnum opus*, the *Bibliotheca Chemica*, John Ferguson displays modestly his erudite and unequalled knowledge of the literature of alchemy and historical chemistry. The mere perusal of this masterly summary provides a liberal education which no chemist should forgo. Here, Ferguson takes the long view of the historian, so salutary to the type of research worker whose main object is to prove the last man wrong:

> The chemistry of the moment is also merely a phase, and by its more rapid development is so much less stable than that of three hundred years ago, when discovery made slower advance. Still the books enumerated here, unattractive as they are—even unintelligible, maybe—record the thought and experience of many men, some of them among the most skilful and far-seeing of their time. . . . Let not the modern student of science imagine that he and his work will escape the universal doom. His discoveries, his theories, the most recent, the most comprehensive and progressive, sooner or later will become mere archaeological data, to be included, or, just as likely, omitted, in a historical review of this time. . . . The history of chemistry, as indeed of all science, is but a succession of epitaphs upon forgotten men and forgotten discovery. . . . It was to mitigate this fate . . . that this gathering of writings of bygone thinkers and workers was made.

A characteristic vein of sentiment sometimes comes to the surface in John Ferguson's writings. The *Bibliotheca Chemica* is dated from his house on his sixty-ninth birthday: 23rd January, 1906; and he ends the introduction, as he says, in the old-fashioned words of old Jean Rey: 'Le trauail a esté mien, le profit en soit au lecteur, et à Dieu seul la gloire.'

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British contributions to biological oceanography

C. M. YONGE

As befits a country which for centuries has ruled the waves and, in spite of U-boats, still rules them, Britain has always been to the fore in the science of oceanography. Here Professor C. M. Yonge, leader of the Great Barrier Reef Expedition of 1928-29, discusses British and other work on the fertility of the oceans.

Water covers over two thirds of the globe. Across these oceans passes the commerce of continents, while within them, from surface to profoundest depths, live innumerable forms of life which constitute a vast reservoir of food and raw material. The exploration and scientific study of the seas form the subject-matter of the science of oceanography. This is not one science but a combination of all, ranging from astronomy and physics to geology and biology. It is, moreover, the most international of sciences: beyond the narrow three-mile limit the seas are the property of no nation but the common concern of all.

Great Britain, as befits the leading maritime nation, has played a great part in the exploration of the seas. To Spain and Portugal belongs the distinction of the first crossings of the great oceans, but Britain claims, in the person of CAPTAIN JAMES COOK, the greatest of scientific navigators. His voyages represent the culmination of the great period of geographical exploration which began with the Renaissance. They also prepared the way for the biological survey of the oceans in all latitudes and all depths which was one of the great achievements of the nineteenth century.

During that period it became the custom of the Admiralty to send naturalists with their surveying vessels. It was in this capacity that DARWIN made his memorable voyage on the *Beagle*, while HOOKER accompanied SIR JAMES ROSS on the first Antarctic expedition, and HUXLEY voyaged to Australian seas in the *Rattlesnake*. By the middle of the century the results of the pioneer dredgings of FORBES, CARPENTER, and WYVILLE THOMSON succeeded in arousing popular as well as scientific interest. To what depth did life extend, and what strange forms of life dwelt in the abyss? Under the tactful stimulus of the Royal Society, the British Government was induced to embark upon an expedition of unprecedented range. In 1872 H.M.S. *Challenger* began a memorable voyage, during which she covered 69,000 miles and circumnavigated the globe, dredging and taking water and bottom samples in all depths and all latitudes. She carried a large scientific staff under the direction of Sir Charles Wyville Thomson.

With the publication of the massive series of *Challenger* reports the modern science of oceanography was established. Life had been found in the greatest depths, vast collections had been made, the nature of the bottom deposits analysed, the chemical and physical properties of the water had been determined and the course of great ocean currents followed. An example had been set that was quickly followed by all the principal maritime nations, which despatched expeditions in all directions. The result was a census of the greatest and most diverse population which exists.

Such a census has little value without knowledge of the mode of life, reproduction and development, and, above all, organization of the complex society it enumerates. Work of this type was initiated at the famous Stazione Zoologica at Naples founded by the German, ANTON DOHRN. Great work was done there by zoologists of all nations, but the broader ecological aspect received little attention. It was not unnatural that in this country, with its great commercial fisheries, the importance of the underlying causes governing the fertility of the sea should have been most keenly appreciated. Many of the basic contributions to

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knowledge on this subject have been made at British marine stations, especially at Port Erin, Lowestoft, Aberdeen and Millport in Scotland, and, above all, at the laboratory of the Marine Biological Association at Plymouth.

The abundance, in total numbers and in diversity of species, of the plankton, i.e. the microscopic drifting life of the surface waters, had been increasingly realized since the middle of the nineteenth century. Now it was demonstrated that these organisms were all-important. The plant-plankton forms the true meadows of the ocean on which, either directly or by way of the small animals of the plankton, the entire marine population ultimately depends. Working at these laboratories with constant access to living animals, zoologists traced the ramifying 'food-chains' and revealed the interdependence of one organism upon another.

The fertility of any marine area was shown to depend on the local production of plant-plankton, but that in turn was controlled by chemical and physical factors. It was early discovered at Plymouth that there is a direct connexion between the summer catch of mackerel and the spring sunshine. If sunshine alone were concerned we should expect an annual increase of plankton in spring and summer, followed by a winter decline. But for the synthesis of proteins from carbohydrates the plant-plankton needs a variety of inorganic salts, especially those containing available nitrogen and phosphorus. Delicate methods for the analysis of these in terms of milligrams per cubic metre were elaborated at Plymouth, and this work has recently been extended to cover a wide variety of elements present in even smaller amounts—but of vital significance. It was shown that the supplies of available nitrogen and phosphorus represent limiting factors controlling the abundance of plant-plankton and so of all marine animals, including food-fishes and whales.

The story of annual events in the sea as thus revealed is of a spring increase followed by decline in early summer due to depletion of inorganic salts. During the winter the shallow seas which border Europe are churned up by storms and new supplies of salts come to the surface, where alone they are available to the plant-plankton. This mixing cannot occur during the summer when the warm surface waters are separated by a thermocline or discontinuity layer from the underlying colder waters. In the open waters of the oceans little such mixing occurs, and their fertility is correspondingly low. Great fisheries occur in regions where the salts from the deep water are available, in shallow seas, where cold and warm currents meet as off Newfoundland, or where deep water 'upwells' along the coast as it does in southern California.

The fertility of British waters is profoundly affected by the influx of Atlantic water, which is rich in nutrient salts. This water enters the approaches to the English Channel and, by way of the north of Scotland, the North Sea. But it fluctuates in volume annually and a clear connexion has been proved between the depth of its penetration and the yield of the fisheries. Although very accurate chemical analysis is necessary to determine the nature of the water, inshore or Atlantic, examination of the water for 'biological indicators' amongst the plankton will give this information at once. The two waters represent distinct environments inhabited by characteristic species.

These facts have led British oceanographers to seek the cause of the vagaries of our fisheries not locally but in the fluctuations of the Gulf Stream, the motive power behind the North Atlantic Drift. To this end observations were begun some years ago at the Biological Station at Bermuda with the close co-operation of American workers from the Oceanographical Institution at Woods Hole. The war has caused a temporary stoppage of this work, but it will be resumed sooner or later. It is the logical outcome of work in British seas.

During the past fifteen years Great Britain has also been engaged on the greatest of oceanographical expeditions since the *Challenger* sailed. Financed out of royalties paid on whales landed at South Georgia, the *Discovery I* and *Discovery II* have studied in repeated voyages the waters and sea-bottom of the Southern Ocean. The life-history, feeding, and habits of Antarctic whales, one of the great natural sources of fats, have been exhaustively examined. Within the tropics over a year of intensive study of coral reefs and coral-reef waters was made by the Great Barrier Reef Expedition, which worked on the north-east coast of Australia in 1928–29. Many smaller expeditions have also been made.

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The cyclotron

F. FAIRBROTHER

In recent years, the word 'cyclotron' has become familiar, but exact knowledge of what a cyclotron is and does is largely confined to physicists and physical chemists. Dr Fairbrother explains the construction and purpose of this complex instrument with a happy blend of simplicity and accuracy, and describes a gigantic cyclotron now under construction.

The alchemists' dream of the transmutation of elements first came true when the late LORD RUTHERFORD in 1919 succeeded in turning a few atoms of nitrogen into oxygen by bombarding them with α-particles from a radium preparation. For many years α-particles emitted from naturally radio-active elements were the only atomic projectiles available until, in 1932, COCKROFT and WALTON at Cambridge, England, were able for the first time to bring about a transmutation by using positive ions accelerated by a high voltage. Other workers have since used increasingly high voltages, but the invention and development of the cyclotron by PROFESSOR E. O. LAWRENCE and his associates at the University of California have made possible the production of atomic projectiles of such high speed that they can penetrate into the nucleus of even the heaviest atom and bring about a wide range of atomic transmutations.

The cyclotron (shown diagrammatically in figure 1) consists essentially of a large electromagnet with circular pole pieces, between which is fixed a shallow cylindrical vacuum-tight metal chamber. Inside this chamber and well insulated from it are two hollow semicircular electrodes, known as 'dees,' rather like a shallow pillbox which has been sliced across its diameter and the two halves separated by a small gap. It is across this gap that the acceleration of the charged particles takes place. The dees are connected to a high-frequency current supply of about 100,000 volts and a frequency of the order of 10^7 cycles per second. The metal chamber is continuously exhausted by large high-vacuum pumps, and either hydrogen, deuterium (heavy hydrogen), or helium, is admitted through a needle valve. Electrons from a hot tungsten filament, striking the gas molecules, produce positively charged protons, deuterons, or helium nuclei, near the centre of the chamber; these are attracted to whichever dee happens at the moment of their production to be negative. Once they reach the inside of one of the dees they are free from the electric field across the gap, but are turned round through a semicircle by the magnetic field. It is a circumstance of fundamental importance that the time taken for such a charged particle to turn through a semicircle depends, not on its linear speed, but on the strength of the magnetic field and the characteristics of the particle. The faster particles follow a wider track and the slower ones a shorter one. By adjusting the electrical frequency and the strength of the magnetic field the particles can be brought round to the gap again just as the electric field reaches its maximum in the opposite direction, when they receive another impulse of 100,000 volts into the other dee. A given particle starting near the centre of the chamber thus follows an ever-widening spiral path, receiving an additional impulse every time it crosses the gap. When the particles reach the limit of the dees they emerge through an aperture in the circumference and

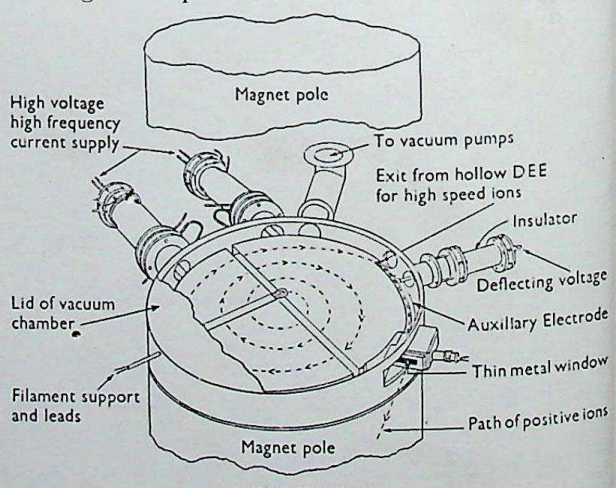

FIGURE 1

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are deflected by an auxiliary electrode through a thin metal window out of the chamber.

The large number of successive impulses given to the particles speeds them up to the same extent as would a single acceleration of many millions of volts, but without many of the insulation difficulties accompanying the latter method. With given particles, the maximum speed attainable depends on the strength of the magnetic field and the radius of the dees; consequently, to attain a very high speed, a very large electromagnet is required.

Many important problems in atomic physics can be attacked with the aid of these high-speed ions, but the chief interest to the chemist and biologist lies in the transmutations which they can effect when they strike a target of a chemical element or compound. Owing to the repulsion between the two positively charged bodies, only a very small number of the projectiles actually collide with nuclei of the target atoms, but when a collision does take place the result is usually a 'nuclear reaction' in which a new nucleus, and therefore a new atom, is formed. This new atom may be one of a different element or another isotope of the target element. Thus, when a beam of several million volt deuterons strikes a crystal of common salt, some of the sodium nuclei of atomic weight 23 become sodium nuclei of atomic weight 24 by the reaction:

$$Na^{23} + \text{deuteron} = Na^{24} + \text{proton},$$

and others become magnesium nuclei:

$$Na^{23} + \text{deuteron} = Mg^{24} + \text{neutron},$$

the protons and neutrons flying away from the target. At the same time some of the chlorine nuclei of atomic weight 37 become chlorine of atomic weight 38 (Cl^{38}).

These products may be stable isotopes like Mg^{24}, or may be unstable and radio-active like Na^{24} and Cl^{38}. The Na^{24} atoms decay into stable magnesium atoms and the Cl^{38} atoms into stable argon atoms, with the emission of an electron in each case, e.g. $Na^{24} = Mg^{24} + \text{electron}$: these emitted electrons have the same character as the β-rays from radium. Other unstable isotopes decay with the emission of positrons, e.g. $Na^{22} = Ne^{22} + \text{positron}$.

This artificial radio-activity was discovered by CURIE and JOLIOT, using α-particles from a naturally radio-active source. A number of radio-elements can be obtained in this way, or

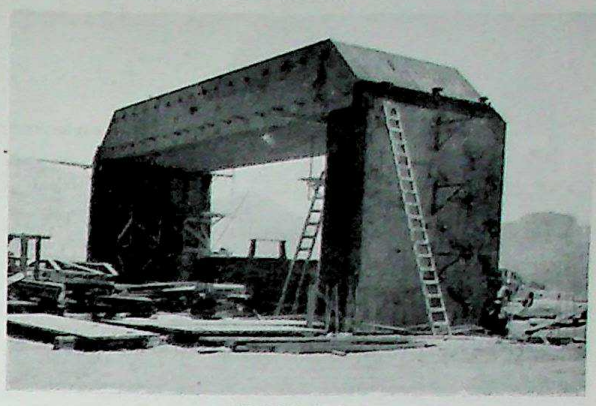

FIGURE 2

by the use of neutrons from a mixture of a radium salt and beryllium powder, but the variety and intensity of the products from the cyclotron are enormously greater.

The actual yield of transmuted elements is so far only to be measured in micro-grams, but the intensity of their radio-activities makes them very easy of detection and measurement. Chemically, they behave exactly like their stable isotopic partners, hence if a small quantity of, say, radio-active chloride be mixed with a quantity of ordinary inactive chloride, the latter becomes labelled by the radio-activity, and the chlorine atoms can be identified even among other atoms of the same kind from another compound, a feat which is impossible by ordinary chemical means. A number of important chemical and biological processes have already been studied in this way, such as the exchange of halogen atoms between organic and inorganic halides, the metabolism of phosphorus and iron in animals, and the movement of inorganic salts in plants.

Cyclotrons have been erected in many parts of the world, including two in England, and have been made larger and larger to obtain swifter particles. The present largest at the University of California has magnet pole faces 5 ft. in diameter, and gives a beam of 16,000,000 volt deuterons or 32,000,000 volt α-particles. Even this is to be superseded by the new cyclotron being built by Lawrence and his team of workers, which is expected to give 100,000,000 volt particles, and may well open up an entirely new field in nuclear science. A photograph (by the courtesy of DR D. COOKSEY) is shown of this new giant in the course of erection (figure 2).

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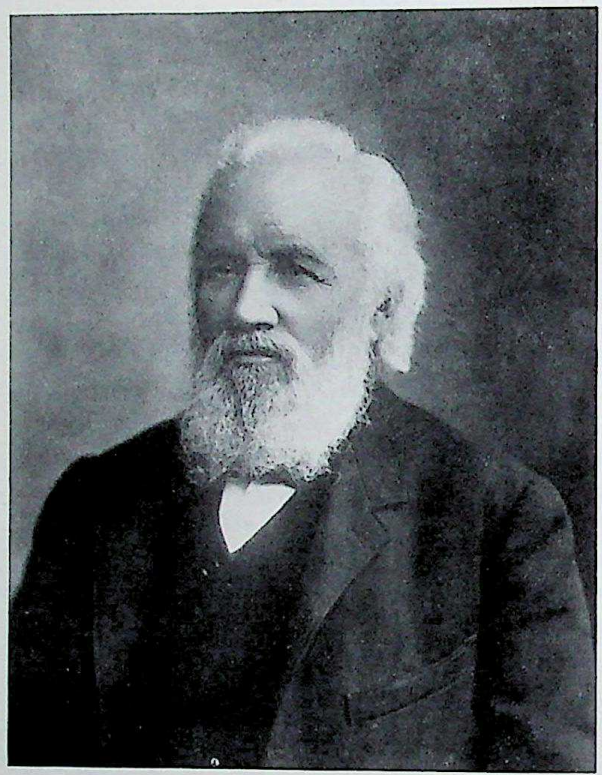
John Glover

N. F. NEWBURY

One of the most fruitful advances in the manufacture of sulphuric acid was the invention of the Glover tower. But the works of reference, biographical dictionaries, and even histories of chemistry had no information about its inventor, John Glover. This strange gap in our knowledge of British chemical pioneers is now filled by Mr N. F. Newbury, who has unearthed details of Glover's life from the obscurity in which they lay.

JOHN GLOVER, inventor of the tower used in the manufacture of sulphuric acid, was born in 1817 at Wallsend, near Newcastle-upon-Tyne. Apprenticed to a plumber, Glover attended the Mechanics' Institute and studied assiduously during slack periods of his work. He was first employed as a plumber, and later as a junior chemist, at the Felling Chemical Works. He suggested useful improvements in the processes used in the manufacture of alum and lead oxychloride.



John Glover.

In 1842 he was appointed manager to the Washington Chemical Works near Durham, a position he held until 1861. Here sulphuric acid was manufactured as an intermediate in the production of hydrochloric acid and magnesium carbonate. In 1861 Glover went into partnership at the Carville Chemical Works, Wallsend, where he remained until his retirement in 1882.

Although Glover visualized his tower about 1847, he was too busy to erect it until 1859. In 1896, when he was presented with the gold medal of the Society of Chemical Industry (awarded for conspicuous service to applied chemistry), he described the conception of the tower in the following words:

> The idea occurred to me that there would be a great saving of expense and material if I could succeed in breaking up the affinity between the sulphurous and nitrous compounds in Gay-Lussac acid without going through the operations of cooling and reheating which were then performed. The first experiment was simply to heat the compound, and the result was to confer on the sulphuric acid a greater power of holding the nitre, not a particle of which was evolved. Then the idea of a deoxidizing atmosphere occurred to me, and that idea was growing in my mind for fully ten years, during which time I devoted the whole of my attention to the erection of a vitriol works for the late Mr Hugh Lee Pattison and the working out of that gentleman's process. Then I returned to my experiments, and by using a deoxidizing atmosphere succeeded in dissociating the sulphurous and nitrous compounds of the Gay-Lussac acid. The experiments were on little more than laboratory scale, but they proved the practicability of my ideas, and the Glover tower was the result.

The first tower, built in 1859 of firebricks packed with fire-resisting tiles and with its base

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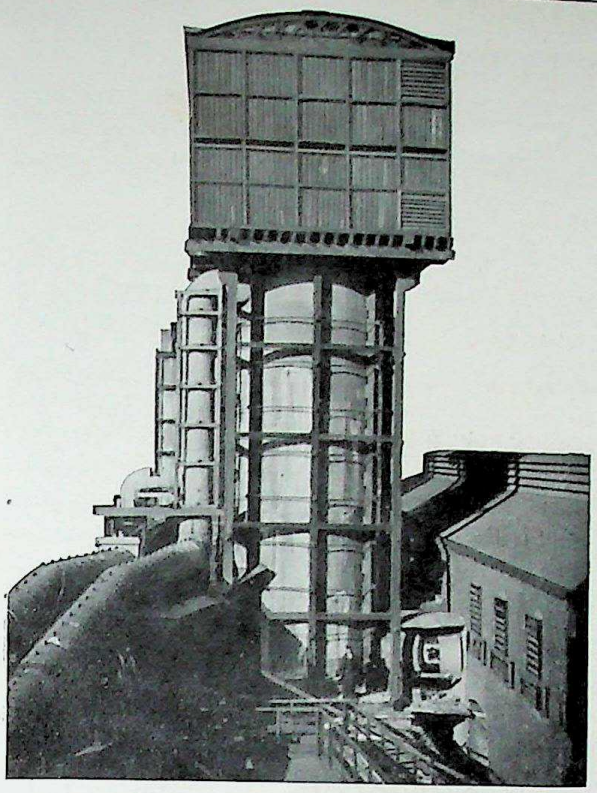

A Glover tower.

fixed in sulphur, functioned efficiently for a year and a half. Many such Glover towers were built, but an improved type (1864), in which the Gay-Lussac acid was diluted with the chamber acid at the top of the tower, was essentially the same in design as those used to-day. Glover, like Gay-Lussac, took out no patent and readily showed his working tower to visitors.

At this time sulphuric acid was usually concentrated either in badly constructed lead pans, resulting in the evolution into the air of the objectionable nitrogen dioxide, or by dilution of the nitrated vitriol with steam or hot water in boxes or steam columns. The Glover tower, however, gradually made headway in spite of opposition, and from 1868 onwards became a familiar sight on Tyneside, in Lancashire, in London, and on the Continent.

The critics of the Glover tower stated that it was expensive to build and too weak structurally to withstand continual wear and tear; that the hot sulphur dioxide reduced the nitrogen dioxide; and that the tower took three days to become warm enough to function. Glover answered these criticisms by quoting facts from his own experience. A tower built in 1868 concentrated 73,000 tons of sulphuric acid to a specific gravity of 1·75 entirely by the combustion of 15,400 tons of pyrites. The initial cost of erecting the tower was £450 and the annual cost of repair over a six-year period was £11. No signs of deterioration were apparent and no oxide of nitrogen was retained in the acid.

The functions and advantages of the tower were many. It resulted in a great saving in fuel and sodium nitrate; the concentrating plant was no longer required; the hot gases passing through the tower were cooled and carried steam into the chambers; and the Gay-Lussac acid was denitrated and concentrated. Further, although Gay-Lussac had designed his tower in 1827, it was not employed to any great extent until it could be used in conjunction with the Glover tower, since it produced concentrated sulphuric acid containing nitrogen dioxide in solution.

Today sulphuric acid of less than 95 per cent. purity is most economically manufactured in a series of Glover and Gay-Lussac towers, without the lead chambers.

Although devoted to study, Glover was friendly, energetic, and generous. Much of his spare time, especially after his retirement, was devoted to welfare work. He served on the committees of the Village Homes for Girls, the Discharged Prisoners' Aid Society, and the *Wellesley* Training Ship. As president of the Newcastle Chemical Society in 1870–72 he made a typical speech dealing with such varied subjects as sanitation, the germ theory, coal-mining, and the Leblanc process, and ended by saying:

> I believe that such of you as devote yourselves to purely scientific investigations, from the promptings of a pure and devoted love, may not, as your reward, gain material wealth, but will have formed what is of infinitely greater value, a noble character and capacity for enjoyment which wealth cannot give you.

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[2] *Ibid.*, 1874, **30**, 120.
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[4] *Ibid.*, 1903, **22**, 1177.
[5] LUNGE. *Manufacture of Sulphuric Acid and Alkali* (Gurney and Jackson).

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THE DEVELOPMENT OF SCIENCE

A Short History of Science to the Nineteenth Century, *by Charles Singer. Pp. xiv* + 399. *The Clarendon Press, Oxford.* 1941. 8*s.* 6*d. net.*

To say that this book is at least as good as others by SINGER is both high praise and simple fact. It is intended for the general reader and fulfils its purpose admirably. The scope is from Greek times to the middle of the nineteenth century, a period in which many leading scientific ideas took shape. It follows a sequence in time and deals with the forward movement of the whole of science. Of many excellent features the sound judgment of the author and his use of recent research are noteworthy. Examples are the correction of the impression that the discovery of humanism was the Greek language and the emphasis of the minor part played by formal scientific method in actual discovery. The clear exposition of the relation of general philosophical ideas to contemporary science is particularly valuable.

The author is scrupulously fair in his treatment of various nationalities in the advancement of science and—apart perhaps from his tendency to underrate the value of the alchemical school—of the importance of the various sciences in the development of human thought. He has no special pleading for the predominance of British science, yet even so its fundamental character in the whole cannot be overlooked. The two Bacons, Hooke, Boyle, Harvey, Newton, Lyell, Black, Priestley, Cavendish, Dalton, Davy, Faraday, Joule, and Darwin come into the period covered, and all exercised an immense influence on the development of science. At the same time, the interchange of ideas between lands in which freedom of thought and speech were fostered is shown to have had a beneficent influence on human progress. The book is written on a high level of scholarship but is never dull or obscure. The author has taken special pains to incorporate the latest results of historical research and, by the skilful division of the text into headed sections and by recapitulations and summaries, to keep the narrative continuous yet preserve its pattern, so that the reader does not lose the thread of the whole on the one hand or the significance of the separate parts on the other. The book is quite outstanding in its field and deserves to be widely read. J. R. PARTINGTON

PLANTS OF THE PAST

An Introduction to the Study of Fossil Plants, *by J. Walton. Pp. x* + 188, *with* 139 *illustrations. A. and C. Black Limited, London.* 1940. 15*s.*

The literature of Fossil Botany is comparatively small and there is room for a concise and general account such as PROFESSOR WALTON has provided. The presentation here adopted has much in common with the type method, one with well-recognized limitations, which are in no way discounted by a basis of selection of such types as are known in respect to both their reproductive and vegetative organs. Although this basis is not rigidly adhered to, the departures are not always those which would appear best suited to enhance the educational value of the theme. For the students for whom this work is professedly written, the inclusion, for example, of *Protopteridium* and *Thursophyton* in the chapter on the Early Vascular Plants, or *Bowmanites Romeri* and *Cheirostrobus* in that dealing with the Sphenophyllales, is dubiously advantageous when room has not been found in the chapter on the Pteridosperms for a description of either *Physostoma* or *Conostoma*, though the structure of these is essential to any adequate appreciation of the range and character of the specialization of the Lyginopteridean seeds.

Of the seventeen chapters, fifteen are devoted to brief accounts of the chief groups of fossil plants. There is also an admirable chapter on the methods of preservation and technique of investigation, which could well have been expanded with profit by the inclusion of a section on that bugbear of all beginners in this field—the interpretation of oblique sections. In this connection it may be emphasized that the elucidation of sections of fossil seeds provides perhaps the best mental discipline in three-dimensional visualization that can readily be found. Another welcome feature is the inclusion of a chapter—far too brief, as it comprises barely three pages of text—on the fossil Angiosperms. Here the statement that 'the rate of evolution

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of the group during the Cretaceous and Tertiary Periods must have been exceptionally rapid' may well be a misrepresentation of the implications of the known facts. All living Angiosperms, even the most specialized aquatics, bear unmistakable evidence of their origin from terrestrial ancestors, so that it is reasonable to suppose that as an essentially land flora, possibly even evolved in relation to dry conditions, the Angiosperms may have had a long history prior to their becoming adapted to habitats likely to favour the preservation of their remains, and the character of the earliest undoubted representatives of the group makes such a suggestion by no means unlikely.

The chapter on the floras and climates of the past is again all too brief. Its six pages scarcely suffice for the display of the skeleton of the subject, still less to clothe it with the flesh of its romance. E. J. S.

SCIENCE FOR THE LAYMAN

The World of Science, *by F. Sherwood Taylor, Ph.D., M.A., B.Sc. New Impression*, 1940. *Pp. xvi* + 1063. *William Heinemann Limited, London.* 10*s.* 6*d.*

DR SHERWOOD TAYLOR'S *World of Science* is probably the best elementary survey of science published in recent years. The accurate treatment of a vast store of scientific knowledge makes it a layman's encyclopaedia, while even the professional scientist will probably find much that is new to him. Beginning with a discourse on the properties of matter considered in the main as aspects of atomic motion, the author proceeds to a discussion of power and its sources and the mechanism of simple machines. Theoretical electricity and its practical application in locomotives lead to a small though adequate treatment of transport. In Part III, on Wave Motion, the treatment of sound includes the mechanism of the gramophone, telephone, and echo-sounder. Electromagnetic waves and quanta serve to introduce light, its laws, the camera, moving pictures, radio and various types of long and short waves. The section on Chemistry proceeds from the atomic theory and an outline of the elements to compounds, formulae, hydrogen, air and oxygen, carbon and the major groups of organic compounds, and certain non-metals and metals. In Geology, Dr Taylor covers aspects of size, shape, movement, and stratified structure of the earth, distribution of land-masses and Wegener's theory of continental drift. The movements of the planets and something of the nature of the universe follow on naturally. The final section on Biology, beginning with cell-structure, leads to a consideration of man, the everyday activities of his body, heredity, and an outline of the classification of animals and the species concept. From the structure, physiology, and reproduction of various types of plant body the author proceeds to a consideration of bacteria and disease, with a concluding chapter on Evolution. The six parts of the book, containing over 1,000 well-indexed pages, are woven into a pleasing pattern. Clear and profuse illustrations and photographs are a feature of the book, which can be highly recommended to teachers, students, and indeed all who are interested in the scientific explanation of the mechanical devices in daily use and the many natural forces at work. J. H. D.

MOLECULAR SPECTRA

The Identification of Molecular Spectra, *by R. W. B. Pearse and A. G. Gaydon. Pp. viii* + 221. *Chapman and Hall Limited, London.* 1941. 42*s. net.*

The complete and accurate identification of the bands in a composite spectrogram is notoriously troublesome and tedious not only to a beginner but often also to an experienced practical spectroscopist. Although several of the existing books on molecular spectra contain tables, diagrams, and reproduced spectrograms which afford the spectroscopist considerable help in this problem, none of these books is designed for the purpose, since the main theme of most, if not all, of them is the analysis of bands and band-systems in accordance with the quantum theory of molecular spectra.

The present work is the first to be planned for the special purpose indicated by its title. It is also a valuable supplement to any of the books to which reference has been made and of which the Physical Society's 1932 *Report on Band Spectra of Diatomic Molecules* is a well-known example.

The book consists mainly of two sections: (i) a table of data for persistent band-heads in order of wave-length, and (ii) a set of lists of data for band-systems in alphabetical order of the molecules, neutral or ionized, to which they

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belong. Comparison of the data for an unrecognized band-system with the data in (i) at once yields a clue to the identity of the system and molecule; then, reference to the data for that system in (ii) indicates the presence or absence of individual bands of the system. This process of double reference is now repeated for other systems of the same molecule and of any other molecule having an atom in common with it. Confirmatory evidence is obtainable from a table of persistent atonic lines and from six plates of well-chosen and beautifully reproduced spectrograms. The book will probably soon become recognized as a necessary item of the practical equipment of the spectroscopic laboratory and as the only trustworthy means of avoiding wrong assignments such as have often found their way into published papers.

W. JEVONS

THE LESS FAMILIAR ELEMENTS

Chapters in the Chemistry of the Less Familiar Elements, *by B. Smith Hopkins. Pp.* 425. *George G. Harrap & Company Limited, London.* 1939. 42*s. net.*

There seems a well-established rule that writers of text-books of inorganic chemistry should treat very briefly or entirely ignore certain so-called minor elements. This is a most unfortunate tradition because it leads many chemists to conclude that such elements are of no account. In 1923 PROFESSOR HOPKINS published his *Chemistry of the Rarer Elements*, which called attention to the great interest and usefulness of these elements and emphasized the need for their further investigation. His book met with a very cordial welcome and has become recognized as an authoritative source of information. Since 1923, however, new elements have been discovered and substantial additions have been made to our knowledge of the rarer elements. Again Professor Hopkins has undertaken the task of trying to convince chemists of the importance of the less familiar elements, and this new volume should achieve its object. The chemist who will take the trouble to read it carefully is assured of a full measure of enjoyment and a broadening of his chemical knowledge. The first of the twenty chapters deals with the Periodic Table, and here Professor Hopkins raises the fascinating problem: Is the Periodic Table complete? His answer contains the statement that 'the existence of many transuranium elements, some with large atomic weights, has been claimed, but these conclusions have been questioned.' This whets the appetite for further information, which is forthcoming in Chapter 18, on uranium. Here the author outlines the story of one of the most intriguing discoveries of recent years, viz. nuclear fission. He could perhaps have emphasized with advantage that the chemical identification of the fission products has demanded an intimate knowledge of the chemistry of many of the less familiar elements. Professor Hopkins might also have reminded his readers that with the discovery of nuclear fission the old arguments for the existence of transuranic elements are no longer conclusive. Chapter 20 is written by E. O. BRIMM, who gives an excellent account of masurium and rhenium. Little can be said about masurium, for 'contributions to our knowledge of masurium from natural sources stopped quite abruptly with the first preliminary announcements of the discovery.' In striking contrast, remarkable progress has been made in the study and chemical properties of rhenium. Turning to the less academic aspects of the rarer elements, it is quite apparent from the sections dealing with their industrial uses and importance in the arts or manufactures that already results of outstanding commercial value have been achieved. The useful alloys, for example, are nests of the less common elements. Again, it is worth remembering that an exceedingly small amount of a substance can frequently produce very great effects. In all the life-processes of both plants and animals substances present in minutest amounts often play a major role. It is to be hoped that this book will stimulate the interest of more English-speaking investigators in the less familiar elements although already their contribution is a notable one. The new volume is pleasant to read and has numerous references, but it should be recorded that in its present form it has a spiral metal binding and is without preface or index. Professor Hopkins and his collaborators have earned the gratitude of chemists for the precise, abundant, and detailed information which they have collected with such care and embodied in such a scholarly production.

W. WARDLAW

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A GERMAN VIEW OF CHEMICAL WARFARE

Chemical Warfare, *by Curt Wachtel. Pp. ix + 312. Chapman and Hall Limited, London.* 1941. 24*s.*

This is indeed a *poisonous* book. Its author, who 'founded' the pharmacological section of the Kaiser-Wilhelm Institute as an assistant to PROFESSOR FRITZ HABER during the last war and who is now, presumably, a refugee from Nazi oppression, resident in America, defines pharmacology as 'that part of medicine which deals with poisons.' All nations, civilized and uncivilized, have always employed poisons for military ends (witness, among other examples, Shakespeare's Hamlet and Macbeth). Germany is therefore entirely guiltless of initiating poison warfare; hundreds of letters from chemists in the trenches poured into the War Ministries of Paris and London during 1914 making the same suggestion. Nevertheless Germany's miraculous scientific organization, inspired by Haber, caught the Allied troops quite unprepared, maintained triumphant superiority in chemical warfare until 1918, and will certainly employ new poisons against our civilian population in the present conflict 'when the political and tactical situation so requires.' Experts who attempt to minimize the prospective mass-slaughter are mere 'pretentious office-holders with no ideas of their own,' undermining by base ruses the reputation of truly capable chemists.

Such an astounding thesis inevitably involves numerous errors and inconsistencies. British chemists have not been backward in their appreciation of Haber (see the magnificent Haber Memorial Lecture by PROFESSOR J. E. COATES, *J. Chem. Soc.*, 1939, 1642), but WACHTEL'S adulation is fulsome and frequently unjust to others. Was Haber, for instance, the 'one man in the world' who knew in December 1914 how the nitrogen of the air could be used to produce the explosives that would frustrate the early victory of the Allies (pp. 29 and 30)? And does the statement, 'medical science knows more poisons than remedies,' justify the conviction that scientific progress dooms us to endure insidious and horrible superpoisons while patients will still die from pneumonia, and 'the unfailing remedy of today will certainly be forgotten in 1943'?

It is curious that the review of American publications in the field of chemical warfare (p. 40) does not include *Chemicals in War*, by COLONEL PRENTISS (McGraw-Hill Book Co., 1937). This invaluable volume is imperfectly cited for the first time in a footnote on p. 201; its title does not appear until p. 210. Several sections of the latter half of Wachtel, however, in which the various toxic chemicals used in 1915-18 are detailed, are obvious transcriptions from Prentiss. An example is the account of phosgene on pp. 154 and 155 (compare with Prentiss, also pp. 154 and 155). Material from other sources is also utilized without proper checking, and this leads to ludicrous inaccuracies. We are told, for instance, on p. 151 that 1 litre liquid chlorine = 463 litres gaseous chlorine at 0° C., and on p. 152 that 1 litre of liquid chlorine forms 434 litres of gaseous chlorine at 25° C., whence it follows that the liquid expands much more rapidly than the gas as temperature is raised! The figure for total gas fatalities in the last war (only 30,000) is a gross underestimate, and many other important data are equally unreliable.

The style is Teutonic in complexity throughout; it is evident that the author still thinks in German even if he has ceased to think as a German. Altogether, a most unsatisfactory production, with a number of pasted-in pages of inferior-quality paper suggesting belated qualms on the part of the publisher. The price is very high.

JAMES KENDALL

PROBLEMS IN ORGANIC CHEMISTRY

Numerical and Constitutional Exercises in Organic Chemistry, *by J. L. B. Smith and Professor M. Rindl. Pp. viii + 213. Methuen & Company Limited, London.* 1941. 7*s.* 6*d.*

All teachers of organic chemistry know that practice in the solution of numerical exercises is a most valuable part of a student's training. It is therefore surprising to find that very few books on this subject are available, and that of those few the best are now out of date. DR SMITH and PROFESSOR RINDL set out to supply the deficiency, and are to be congratulated on the result. Their book is a well-designed and admirably executed scheme, and the student who works through it conscientiously will not only have attained a thorough grasp of the main principles of elementary organic chemistry but will be in a position to interpret the data he obtains when he begins original research.

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Notes on contributors

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SIR WILLIAM BRAGG,
O.M., K.B.E., F.R.S.

Is one of the best-known names in contemporary science, and a scientist who has won international honour in the world of physics. Sir William originally made his mark with his researches in connection with the elucidation of crystal structure by X-ray methods, in which work he has since been joined by his distinguished son, Professor Sir W. L. Bragg. Father and son are known as outstanding authorities on their subject. Sir William has gained wide scientific distinctions and has the award of the rare Order of Merit, of which there are only twenty-four holders. He has recently completed his term of office as President of the Royal Society.

H. SPENCER JONES,
M.A., Sc.D., B.Sc., F.R.A.S., F.R.S.

Has held the position of Astronomer Royal since the year 1933. Dr Jones was born in London in 1890 and was educated at Latymer Upper School, Hammersmith, and Jesus College, Cambridge, where he had a brilliant academic career. From 1913-23 he was Chief Assistant at the Royal Observatory at Greenwich, and from 1923-33 held the post of His Majesty's Astronomer at the Cape of Good Hope. He is known throughout the world not only for his distinguished original contributions to astronomy but for his skill in explaining to laymen the most abstruse astronomical and cosmological conceptions and theories.

C. H. WADDINGTON,
M.A., Sc.D.

Is one of the most brilliant of the younger school of British scientists. He was born in 1905 and educated at Clifton College and Sidney Sussex College, Cambridge. He specializes in the study of heredity, and particularly in that branch of it known as genetics. He has wide interests and the gift of virile and fluent expression. He has held the Gerstenberg prize for embryology of the Royal Belgian Academy, and is at present a Fellow of Christ's College, Cambridge.

J. G. CROWTHER

Is well known as a scientific journalist, as well as being the secretary of the Science Committee of the British Council. He holds the position of scientific correspondent of the *Manchester Guardian* and is author of several successful books on science for the general reader. He has travelled extensively in America and Europe as well as in the Soviet Union, and has first-hand knowledge of many of the most up-to-date scientific laboratories in the New World as well as the Old.

A. L. BACHARACH, *M.A., F.I.C.*

Is one of the foremost authorities on nutrition and dietetics in the British Isles. He was born in 1891 and was educated at St. Paul's School and Clare College, Cambridge. On taking his degree he entered industry by way of the Wellcome Chemical Research Laboratories. After working there for some time he joined the staff of Glaxo Laboratories Limited in January 1920, and is now head of the biochemical department of this firm. He is the author of a large number of papers, reviews and technical articles and is honorary treasurer of the newly formed Nutrition Society.

G. V. JACKS, *M.A., B.Sc.*

Has specialized in 'soil science' since his graduation from the university. He is 40 years of age and was educated first at Magdalen College School and afterwards at Christ Church, Oxford. He was there awarded a post-graduate research scholarship by the Ministry of Agriculture and travelled extensively in Germany, Scandinavia and Russia. From 1929-31 he was Lecturer in Soil Science at the Imperial Forestry Institute, Oxford, and has since held the post of Deputy Director of the Imperial Bureau of Soil Science at Rothamsted.

JOHN READ, *Ph.D. (Zürich), M.A., Sc.D. (Cantab.), F.R.S.*

John Read is a Somerset man and proud of it. Born in 1884, he was educated at Sexey's School, Bruton, Finsbury Technical College, and the Universities of Zürich, Manchester, and Cambridge. He is Professor of Chemistry in the University of St. Andrews, to which he was translated in 1923 after seven years as Professor of Organic Chemistry in the University of Sydney, Australia. He is an authority on the chemistry of the natural products of Australia, on stereochemistry, and on the history of chemistry.

C. M. YONGE, *Ph.D., D.Sc.*

Is another of the younger scientists. He has trodden in the footsteps of Captain Cook. He was born in 1899 and educated at Silcoates School, Wakefield, and at Edinburgh University. After a period of research work, he became, in 1925, Assistant Naturalist at the Marine Biological Association, Plymouth, and two years later went to Cambridge as Balfour student. In 1928 he led the Great Barrier Reef Expedition to Australia, and on returning in 1929 went back to the Marine Biological Association at Plymouth as physiologist. Since 1933 he has been Professor of Zoology in the University of Bristol. He is also a member of the Advisory Committee of Fishery Research to the Development Commission and has published a number of books and papers on biology.

F. FAIRBROTHER, *D.Sc.*

Is Lancashire born, bred, and educated. He was born in 1894 at Heywood, and educated at Manchester Grammar School and Victoria University, Manchester. Since 1919 he has been a member of the staff there and now holds the title of Reader in Inorganic Chemistry. His researches have been chiefly in connection with electrokinetic phenomena, dipole moments, and electrolytic dissociation processes. In 1936 he was awarded a Leverhulme Research Fellowship and spent the year 1937 in California working in the laboratories of Professor E. O. Lawrence at Berkeley and of Professor Linus Pauling at Pasadena.

N. F. NEWBURY,
M.A., M.Sc., A.I.C.

His chief experience has been in the field of education. He has had seventeen years' experience of teaching, and is also the author of several books dealing with the subject. He is a graduate of Sheffield University and also of Liverpool University.

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ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

VOLUME I APRIL 1942 NUMBER 2

The future of research

At the moment, the pursuit of knowledge for the sake of knowledge—the Hellenic ideal—is at the lowest ebb throughout the world. In many countries there are neither means nor men to conduct it: in some it is frowned upon as not practical politics. In those which lie under the Axis yoke, indigenous research has been suppressed with every effort at thoroughness that organized brutality can command. Colleges, technical institutions, and universities have been closed, their staffs and students persecuted if not murdered. Scientific textbooks have been burnt, scientific journals compelled to cease publication, scientific societies forcibly dissolved. Yet even in such adverse circumstances the spirit of science has not been extinguished. Stirring accounts have come through of Chinese men of science imperturbably pursuing original investigation in dimly lit caverns, in the depths of forests, and in mountainous recesses. Similar quiet determination is being shown by their counterparts in every part of the enslaved or threatened world. We salute these indomitable souls and bid them be of good cheer, for the day will surely come when their sublime ardour will be rewarded.

What of science in Allied and Axis countries? In both camps the main and practically sole activity of scientists is directed towards the solution of immediate problems of offence and defence, of transport, nutrition, health, and of the thousand other factors that go to make up a total war. Research has one object—to increase the efficiency of the war effort.

Since, therefore, the world of science has been driven by *force majeure* into a position in which its orientation is determined wholly by social conditions, the time is opportune to inquire whether this orientation is not in fact the optimum for peace as well as war. There are in Great Britain many influential scientists who would answer such an inquiry with an unqualified and uncompromising affirmative. To them, knowledge is of value only in so far as it is capable of application to the amelioration of human existence; and, on the principle of first things first, they would urge that the full capacity of science be turned to present needs. In the absence of the urgency of war, it is clear that no such uniformity of direction could be achieved without complete state control, which must therefore be regarded as an essential element of future policy.

No one will deny that the justification of science is the service of humanity. The danger lies in any attempt to convert science from a willing collaborator into a regimented slave. There has admittedly been in the past a wastage and overlapping of effort through lack of co-ordination, and, *per contra*, much important scientific knowledge has been acquired by the deliberate focusing of research ability upon individual commercial or industrial problems. But social and political systems change, often with bewildering rapidity, while the corpus of science develops continually and continuously. To try to force that corpus into any predetermined mould is likely to prove fatal to both—though fortunately the vitality of science, as its history has repeatedly demonstrated, is capable of withstanding extremes of rigour.

The ideal to be aimed at in the development of scientific research is not mechanization of the whole army of workers, for there can be no reasonable doubt of the dreary mediocrity that would follow or of the scientific genius that

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would fail to flower. Imagine NEWTON, with no leisure for physics or mathematics, compelled to spend his days devising new methods for assaying bullion, FARADAY commanded by GLADSTONE to discover 'something useful,' or EINSTEIN instructed by a government department to check the tables of seven-figure logarithms! That these are not tendentious exaggerations of what might happen is abundantly witnessed by the records of all governments in all countries and at all times. Let us indeed have more co-operation, more pooling of information, more purposeful and economical direction of research, but let us resolutely withstand the deadening fetters of bureaucracy.

Freedom for the scientist to follow his own bent is, in fact, the *sine qua non* of vigorous scientific progress. If an individual scientist adds to our knowledge of natural phenomena, he has justified his existence, even if the facts he discovers are of no apparent use to the community. No knowledge of Nature is inherently useless, and no one can say that the seemingly trivial observation may not become significant. CAVENDISH'S eighteenth-century bubble of argon was a chemical *objet d'art;* today the applications of this gas are so extensive as to necessitate its extraction on an industrial scale. And, happily, there are still those who inquire into the nature of things because 'all knowledge and wonder (which is the seed of knowledge) is an impression of pleasure in itself.'

Correspondence

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., Imperial Chemical Industries, Nobel House, Buckingham Gate, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

FACILITIES FOR INDUSTRIAL AND GOVERNMENT SCIENTIFIC WORKERS

From A. V. Hill, O.B.E., M.A., Sc.D., F.R.S., M.P., *Secretary of the Royal Society*

It is essential, for the good of their souls (and their work), that scientific people employed in industrial and Government laboratories should, in ordinary times, enjoy similar facilities as exist in universities and research institutions:

(*a*) for discussions, lectures, colloquia, visits, attendance at meetings of learned societies, etc. (i.e. for making their science part of their social life, and vice versa);

(*b*) for travel, and for exchange (temporary or permanent) with other laboratories at home and overseas;

(*c*) for receiving visiting and (where possible) foreign co-workers; and

(*d*) for publication of results: secrecy is sometimes necessary, mystery never.

A man's work should be judged by his peers. Without proper facilities this is impossible, and disappointment or complacency, with consequent sterility, may result.

As a preliminary to action on these lines after the war, ENDEAVOUR might invite contributors to put on record now what the facts are as they have found them.

CO-OPERATION BETWEEN UNIVERSITIES AND INDUSTRIAL TECHNICAL STAFF

From R. E. Slade, M.C., D.Sc.

The problem of arranging closer co-operation between academic science and industrial research, discussed in PROFESSOR ANDRADE'S letter [in this Journal, Vol. I, No. 1, p. 7], deserves consideration by those responsible for the direction of industrial research. The views of other academic scientists would also be of interest.

From the start, industrial research has been based upon the use in industry of the outlook and methods of research developed in university laboratories. And industry needs a constant flow of younger men into the laboratory

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from the university schools in order to ensure new technique and fresh vision. It is from the universities that industry seeks a newer and broader outlook upon science.

Although it has, in the past, been the opinion of some academic scientists that the university professor should have no relations with industry, the adoption by industry of academic discoveries in recent years has inevitably brought an increasing number of professors into a closer contact with the men actually engaged in production. When this has taken place, I believe a closer understanding of each other's viewpoint has always followed. The chemical industry has achieved a measure of collaboration, but we are conscious that much more may be done without running any risk of turning the professor into an industrial research worker—which would defeat the aim. In our earliest approaches to the academic scientist we sent men to work with a professor for a period up to three years on a subject chosen by him. This enabled our research managers to visit the professor from time to time, and gave opportunities for scientific discussions of mutual interest.

Frequently we ask a professor to allow one of our research workers, or a man chosen by the professor, to work in his laboratory on some subject in which we are interested, allied to that on which the professor is working. In some of our laboratories committees, including university professors, meet monthly to consider the researches in progress. At others a few professors come at regular intervals to spend the day. Any research worker is thus able to discuss with them any problem he likes. This procedure, which seems to work well, is very similar to Professor Andrade's suggestion. It is preferable to discussions taking place in a committee as it allows closer contact between the professor and junior research workers. No doubt, no one system of collaboration will be found perfect, but I am convinced that industry should welcome contact with academic scientists.

THE VELOCITY OF SOUND

From Charles Graves, M.A.

I have been most interested to hear our fighter pilots discuss apparent vagaries in the speed of sound. It seems that they frequently observe phenomena which they believe incompatible with the textbook figure of 1,100 ft./sec. May I suggest that an article on modern measurements of the velocity of sound, of various notes and under various conditions, would be welcome in an early number of ENDEAVOUR?

NATIONAL PARKS

From E. B. Worthington, M.A., Ph.D., *Director of the Freshwater Biological Association, Wray Castle, Ambleside*

The letter from DR JULIAN HUXLEY [Vol. I, No. 1, p. 7] raises problems on which I would like to add a note or two. The establishment of National Parks in the British Empire has been retarded by the reluctance of administrators to take responsibility for locking up great tracts of country for all time against development by human beings. If it can be recognized that some forms of human endeavour, in addition to those purely scientific and educational, are not incompatible with the objects of National Parks, their establishment would clearly be facilitated.

The most obvious financial return comes from the tourist traffic, and it is satisfactory to know that the Kruger National Park was by 1937 practically balancing its annual expenditure from this source. Apart from tourists, however, every acre of land or water cannot help but produce its annual crop, and I suggest that the development of some forms of animal and plant products is not impossible in National Parks.

For example, the Edward Nyanza lies partly in the Parc National Albert, where the killing of all animals, including fish, is forbidden. In part of the lake which lies in Uganda, however, a native fishery has been developed since 1935, and by 1939 produced more than 1,000 tons of dried and salted fish a year, worth £24,000. This fishery if properly controlled is not likely to cause the loss of unique species which inhabit that water, and it would be an asset rather than the reverse in the event of the area in which it lies being declared a National Park.

Coming nearer home, the conversion of an area such as the Lake District into a National Park would not prevent fishing in the lakes or the use of the fells as sheep-grazing. Rather would it stimulate the scientific development of natural resources, often to the advantage of the area.

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Physical research on problems of soil cultivation

B. A. KEEN

Dr Keen's article challenges many traditional ideas about agricultural methods. In particular, he brings evidence to show that, contrary to deeply ingrained tradition, crop yields are remarkably insensitive to variations in cultivation; and that the attractive 'capillary tube' theory of the movement of soil moisture is entirely untenable. The work described is likely to have far-reaching effects upon agricultural thought.

When the scientist first seriously turned his attention to agriculture he was confronted with traditions—true, partly true, and false. The beginnings of agricultural science were to a considerable extent concerned with the examination of these traditions, with the separation of truth from falsehood, and with their restatement in scientific terms. Agricultural science is a young growth, for although the literature shows that, almost from the beginnings of scientific inquiry, attention was given to agriculture, such attentions were in the nature of incursions. The present-day agricultural research laboratories, staffed by chemists, biologists, physicists, and even mathematicians, are, with rare exceptions, the product of the past fifty years. The physicist was a late arrival to this team. It is true that a century ago SCHÜBLER, in Germany, worked almost exclusively on the physical properties of soil and that, in Britain, SIR HUMPHRY DAVY'S *Elements of Agricultural Chemistry* balanced his somewhat backward notions of soil chemistry by stressing the importance of soil physics; but before those pioneer works could be followed up the brilliant researches and field experiments of LAWES and GILBERT at Rothamsted, which overthrew the much-advertised ideas of LIEBIG on plant nutrition, had brought soil chemistry and biology to a position where a complete theory of soil fertility seemed within easy grasp. Soil physics fell into the background and remained there until the latter part of the nineteenth century. Its re-emergence was due largely to United States workers: especially HILGARD in California and KING in Wisconsin. In the climatic and soil conditions of America the remarkably swift spread of arable agriculture over that continent had thrown up urgent soil problems. Hilgard was specially concerned with irrigation and soil-alkali problems, and King, working under higher but still insufficient rainfall conditions, made important practical studies on the effects of tillage operations on the moisture content of the soil. In the more settled agricultural conditions of Europe there was a less striking but steady revival of interest in soil physics, marked by the appearance, over the years 1878–98, of a German journal, edited by WOLLNY, devoted entirely to original articles on the physical properties of soils and plants and on agricultural meteorology. At the end of the nineteenth century soil physics had become a recognized branch of agricultural science. WARINGTON, at Rothamsted, summarized the existing knowledge in an excellent little book, *The Physical Properties of Soil*. But the subject was outgrowing its existing theoretical framework. The time was ripe not only for a critical re-examination of the framework by competent physicists, but for its extension to include a study of the colloidal properties shown by all finely divided materials. In Great Britain the subject was reopened at Rothamsted in 1913. Much attention has been given to field and laboratory studies of the laws of moisture-movement in the soil and to their practical bearing on tillage operations and crop growth. Alongside this work, long-range researches on the physical and physico-chemical properties of clay were made, because in the vast majority of soils this finely divided

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material has a controlling influence on soil properties and behaviour.

It is instructive for the present purpose, and fascinating in its own right, to trace over the past few centuries the parallel development of improvements in cultivation implements and the growth of ideas on the physical properties of soil. It is appropriate to confine attention to British conditions, for although 'high farming' originated in Flanders, it was quickly adopted in Britain, and under the urge of the Industrial Revolution Britain took the lead in applying mechanical invention to farm implements.

For conditions up to the end of the fifteenth century, the main sources of information are the surviving illuminated manuscripts and tapestries. These show very clumsy ploughs (figure 1), heavy in draught and quite incapable of turning the almost unbroken furrow-slice of the present-day plough. Rough large clods were left and had to be broken down by wooden mallets (figure 2). The importance attached to malleting as a mitigation of inevitably poor ploughing is possibly reflected in the variety of names the mallet enjoyed: maul, mattock, clotting beetle.

In 1523 FITZHERBERT'S *Boke of Husbandry* appeared—the first book in the English language on practical agriculture. From it we learn that the art of soil cultivation was well established. Ploughs varied in design from district to district in an endeavour to meet the requirements of the different classes of soil, and the setting of the implement could be varied to give broad or narrow, deep or shallow, furrows. The setting was a formidable operation involving the adjustment of wedges in various slots, and as to the setting of the share itself, Fitzherbert aptly remarks: 'It is harde to make a man to vnderstande it by wrytynge, without he were at the operation therof, to teache the practyue.'

Interspersed in Fitzherbert's technical instructions for adjusting and using implements we find occasional evidence that he was forming ideas on the physical properties of soil. He recognized the crumbling effect, on heavy soil laid up in ridges, of frost and alternations of dry and wet weather. One of his practical directions may be regarded as a simple experiment on soil tilth: one of the earliest on record. To see whether the land is fit for sowing peas and beans the husbandman is told to walk over the ploughed land, 'and if it synge or crye, or make any noyse vnder thy feet, then it is to wete to sowe: and if it make no noyse, and wyll beare thy horses, thanne sowe in the name of God.'

In the seventeenth century there was steady but slow progress in plough design, and BLITH, in his *English Improver Improved* (1652)—which was copiously quoted by writers up to the end of the century—insisted that the draught of ploughs was too great because of lack of care in the construction and setting of the implement. He fully realized that the crux of the matter was to secure a smooth and natural curve over the region where the rear of the ploughshare met the mouldboard. Otherwise the furrow-slice suffered an abrupt change of direction in this angle, which became clogged with soil, thus greatly increasing the draught.

Until the closing decades of the seventeenth century there was little or no progress in the scientific study of soil problems. Thus MARKHAM, a prolific agricultural writer, was content with a purely armchair classification of soils into 'simple' and 'compound.' Simple soils had no mixtures with others of contrary quality and were either loose sands or stiff clays. Simple soils, however, could be 'diverse': black clay, blue clay, 'clay like unto marble,' coloured sands, and 'sands like unto dust.' The compound soils consisted of clays and sands 'equally or indifferently mixed together.' In contrast with this procedure, which is limited only by the ingenuity of its practitioners, it is refreshing to read of HOUGHTON'S experiment, published in his *Collection of Letters for the Improvement of Husbandry and Trade* (1681). Houghton was a Fellow of the young, but well-established, Royal Society, some of whose members were also applying the new spirit of scientific inquiry to agricultural problems. The leaven was at work. The account that follows is taken from MORTIMER'S *Whole Art of Husbandry* (1706):

> An Experiment of Mr Houghton, to know what quantity of Sand any Earth or Marle is mixed with, which may be of use to try the nature of several sorts of Land by: He took a piece of Clay such as the Brewers stop their Cask with which is commonly a sort of yellow

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Tyle-clay, which weighed 4 Ounces ½ Averdupois, which he dissolved in Water, and poured off the thick into another Bason till all was gone but the Sand; which stuck not together, but lay loose in the Water, and when it was dry would run like Hour-glass-sand, of which he had about the quantity of an Ounce, being of a yellow colour and something glistening, and some little Stones and other foul matter was with it; and when the Clay was settled he poured off the Water, and left the rest to dry in a Pewter-bason, which hung together, only 'twas full of Cracks.

He tryed likewise Fullers-earth which left a thick settlement, which when dry would easily break to powder, but he could find no Sand in it; neither by the Microscope, nor any Grittiness by rubing of it between his Fingers.

In this simple experiment Houghton obtained not only a measure of the proportion of fine and coarse material in his samples, but also observed differences in their physical properties. He records also some entertaining speculations on the relations between soil and its moisture content. He postulated irregular configurations for the soil particles: 'like a pear, big at one end and small at the other,' 'long with two ends,' 'eight cornered, or of several other figures, by which means they cannot run as water and oil that are supposed round.' Hence the indefinitely divisible spherical pieces of water could penetrate between the soil particles, unless these were so shaped as to lie very close together. In this case only the smallest water globules could enter; the layer would be moist but would not drain. Clearly, Houghton was here trying to explain to himself why impervious clay strata may yet be moist.

The eighteenth century produced rapid advances. TULL'S *New Horse-Hoeing Husbandry* (1731) heralded a revolution on the practical side of soil cultivation, while technical improvements in plough design and construction brought the implement to substantially its present-day form. The Rotherham plough (figure 3), named after its Yorkshire factory, had only one half the draught of the common plough. It seems to have been a development of the Dutch plough, and in fact it was known in Scotland as the Dutch or patent plough. The early history of the Rotherham plough is rather complicated and not free from sharp practices connected with the leakage of trade secrets. The mouldboard was made in wood and cased with an iron plate. There is a strong presumption that the mouldboard shape was derived from quite simple geometrical principles and that these formed part of the trade secrets. Whether this was the case or not, towards the end of the century the geometry of the mouldboard was public property. JAMES SMALL, a 'Plough and Cart Wright' of Edinburgh, and that remarkable man THOMAS JEFFERSON—author of the Declaration of Independence and Third President of the United States—both arrived independently at the solution.

Small made many ingenious experiments, using a spring balance to measure plough draught and constructing his mouldboard of soft wood so that places where excessive frictional wear occurred would show up quickly. He assumed that the ideal shape for efficient work and minimum draught would necessarily be the one that had equal frictional wear over its whole surface. He found that this gently and regularly twisting surface could be set out on a simple geometrical construction, and in his *Treatise on Plough and Wheel Carriages*, published in 1784, he gave the method in detail.

Jefferson's solution of the problem is typical of the man. In his *Journal*, preserved in the Library of Congress, there is a comment, dated 1788, on the clumsy ploughs he saw during a tour in Germany. This entry is followed by his views on the correct principles of mouldboard design and a geometrical method of construction. Some five years later he constructed ploughs to his design and used them on his estate.

The basis of these constructions, of which there are many variants, is that the furrow-slice is simultaneously raised, moved bodily to one side, and twisted. Small's method was intended to raise the slice and move it sideways by equal amounts for each unit of forward travel of the plough, and at the same time to give the slice equal increments of twist until, at the rear end of the mouldboard, the under surface of the slice had rotated through 130° and was, therefore, lying at an angle of 50° with the horizontal. The principle of the construction was to mark 130 equal divisions along a block of wood of suitable length, and then, beginning at the front, the wood was cut away until the angle made by the cut surface

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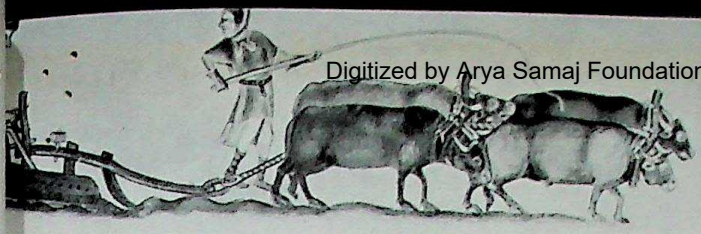

E 1 – *A mediaeval plough. (Luttrell Psalter, fourteenth century.)*

FIGURE 2 – *Malleting. (Luttrell Psalter, fourteenth c*

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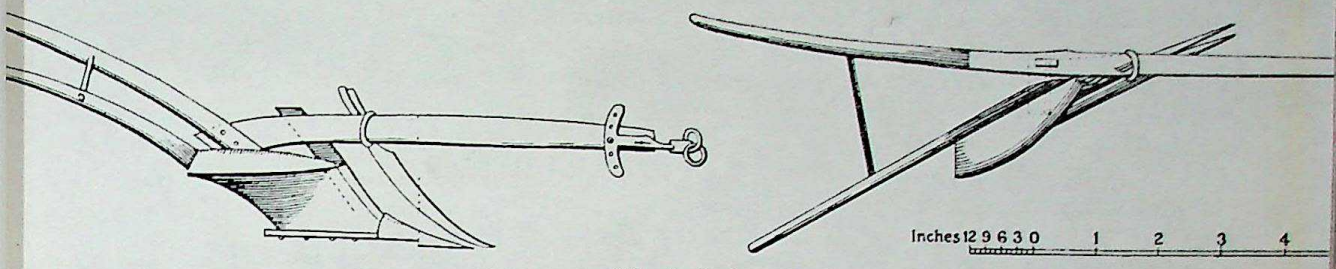

FIGURE 3 – *The Rotherham plough.*

and the bottom at any point was equal to the scale number at that point. The steps were smoothed off, and an iron plate, which formed the actual mouldboard, was shaped to the wooden pattern.

Very little further information on plough design was published after Small's treatise. The nineteenth century produced a bewildering variety of mouldboard patterns, many of which were, beyond doubt, redundant. All these forms, in fact, approximate to a fundamental form which, as BOUSFIELD showed in 1880, can be generated by projection from the successive positions of the furrow-slice itself. Bousfield's method can be followed from figure 4 (*a*), which shows the cross-section of the furrow-slice in the original, vertical, and final positions. In the first 90° it turns around point A, and thereafter around point D_1. Figures 4 (*b*) and 4 (*c*) show respectively the generated plan and side elevation of the mouldboard. The total angle through which the slice is turned is subdivided into equal smaller angles (ten, each of 15°, in this illustration). The length XY of the mouldboard is divided into the same number of equal parts and perpendiculars erected. The outline of the mouldboard is given by the intersections of these perpendiculars with the corresponding lines—drawn parallel to XY—from the ten successive positions of the generating line.

The fundamental form of mouldboard is thus helical only for the first 90° of twist during which it revolves around point A in figure 4 (*a*). If the whole twist were helical, the slice would ultimately have to occupy the dotted position. The remaining twist beyond the vertical is, in effect, accompanied by a sideways displacement of the slice from the dotted position to $A_2B_2C_2D_1$, so that the rear portion of the mouldboard is helicoidal, not helical.

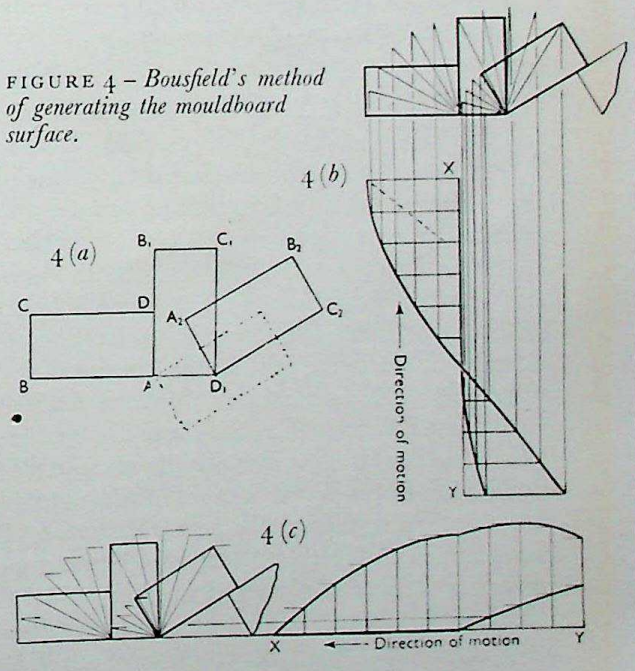

FIGURE 4 – *Bousfield's method of generating the mouldboard surface.*

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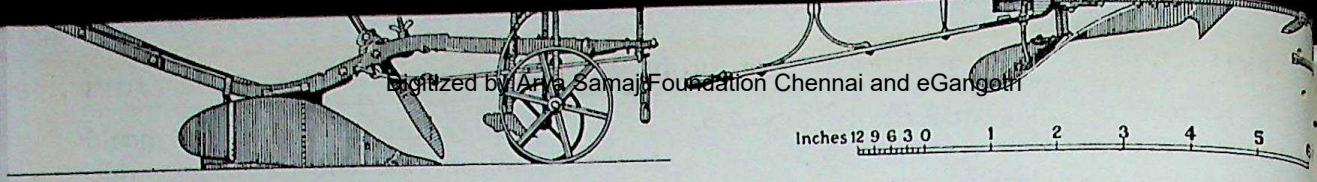

FIGURE 5 – *The modern plough.*

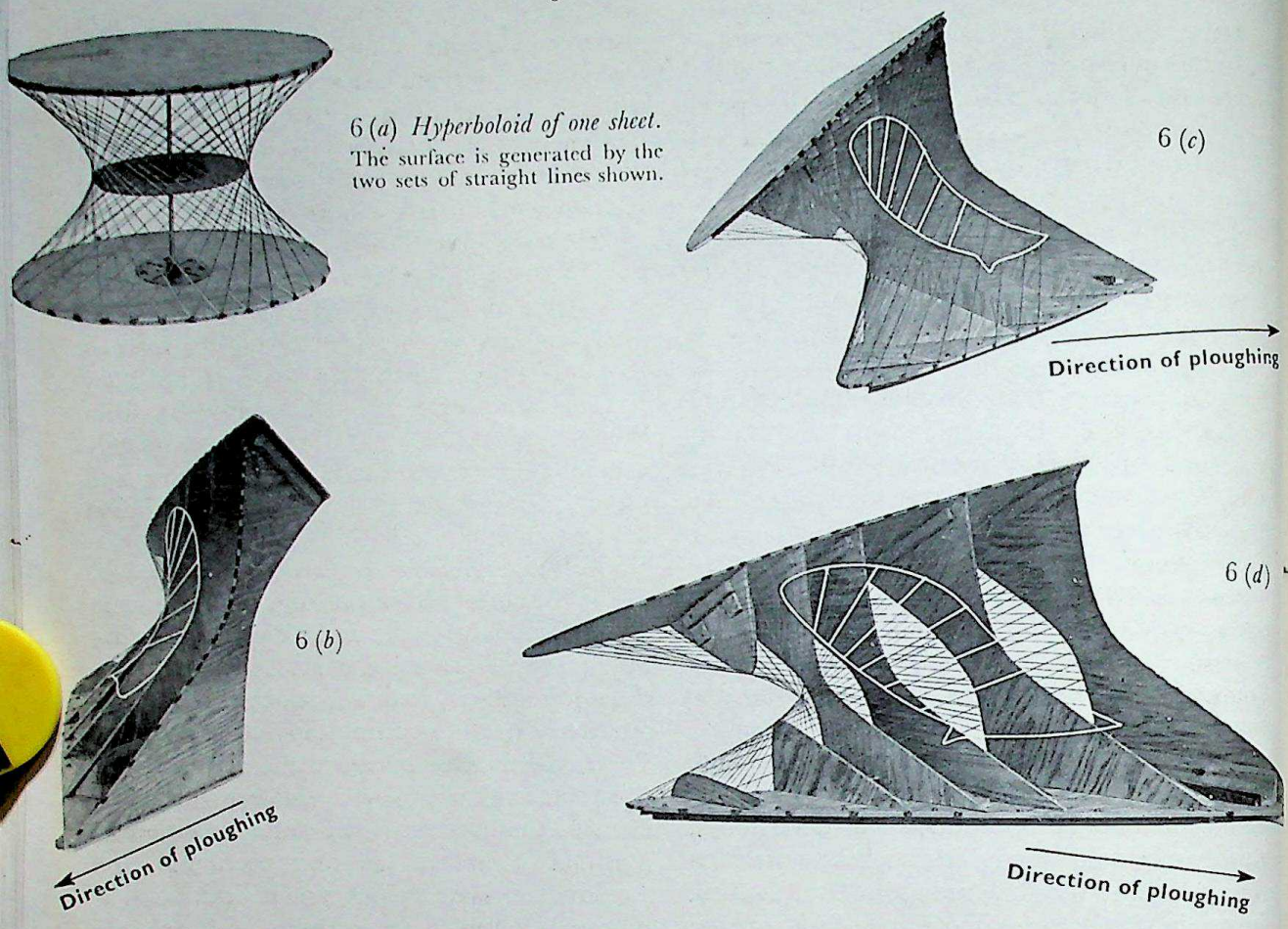
6 (a) Hyperboloid of one sheet.
The surface is generated by the two sets of straight lines shown.
6 (c)
Direction of ploughing
6 (b)
Direction of ploughing
6 (d)
Direction of ploughing

FIGURE 6 – *Models illustrating White's analysis of an American mouldboard.*

This fundamental form is a good approximate representation of the modern British plough. The geometrical construction, however, contains the implicit assumption that a vertical section of the furrow-slice moves in and remains in its original plane or that the soil shears in the same way as a pack of cards. But later work in the United States has shown that there is a twisting of these imaginary planes as the mouldboard moves forward underneath them. Apart from this, there are certain practical requirements necessitating some modification in the derived shape. The cutting edge of the ploughshare lies in the direction of the dotted line (figure 4 (*b*)); this line necessarily lies below the helical surface, so the curvature is altered to merge smoothly into the ploughshare. The construction of figure 4 makes the mouldboard width over its whole length equal to that of the furrow-slice; this is unnecessary, for the slice possesses some cohesion and so the mouldboard width can be reduced, thus saving metal and improving the outline. Over the helical portion of the mouldboard there is a tendency for the slice to be pulled sideways instead of turning on the point A; it has been found that this can be reduced if the generating line is convex towards the bottom of the slice and not straight. Over the helicoidal portion the convexity is progressively reduced to linearity. To press the furrow-slice well home, the tail end of the mouldboard is commonly given a slightly sharper twist.

The approximation of Bousfield's geometrical construction to the form of the modern plough

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can be seen by comparing figures 4 and 5. The mouldboard shown in figure 5 aims at turning over the furrow-slice more or less intact and is used mainly in countries where the winter is relatively mild. Frost and the alternations of wet and dry spells produce a progressive disintegration of the furrows, so that in the spring they can easily be worked down into a seed-bed.

In Continental areas where there is a hard winter and the ground is frozen to a considerable depth, autumn ploughing is rarely done. Hence, in the spring, speed of work in ploughing to get a seed-bed quickly is of great importance. The ploughs for this purpose are sharply curved, something like a concave scoop, so that the furrow-slice is partly disintegrated in its passage over the mouldboard. A study of the common types in use in the United States has been made by WHITE, who found that they form part of the surface of a geometrical figure known as a hyperboloid of one sheet, whose equation, with the centre of the figure as origin, is $x^2/a^2 + y^2/b^2 - z^2/c^2 = 1$. It is a vase-shaped surface (figure 6(*a*)), whose actual configuration depends on the values given to the constants a, b, and c in the equation. A property of this figure is that two sets of straight lines lie wholly in the curved surface. By exploring a mouldboard surface with a straight-edge White was able to pick out the two sets of straight lines, and then, by tedious but straightforward arithmetic and analytical geometry to derive the equation for the hyperboloid of whose surface the mouldboard formed a part. A model of the relevant portion of the surface, constructed from White's equation for one plough, is shown in figures 6 (*b*), 6(*c*), and 6(*d*). The outline of the plough and one of the two sets of straight lines generating its surface have been fashioned out of stout wire and whitened, so that their position on the surface of the hyperboloid may be clearly seen.

Although White's analysis gives a close geometrical approximation to the shape of the concave, or 'digger-breast,' type of plough, it cannot, without much further research, offer guidance in the converse problem of synthesis. For this purpose one would have to predict the best values of the constants a, b, and c to produce a plough to meet any given set of practical requirements, and to specify—by giving the equation of the mouldboard outline—whereabouts on the hyperboloid the mouldboard would lie. A further point, which throws some doubt on the practical use of the above analysis, is that the two sets of straight lines, which are the fundamental definition of the mouldboard surface, have no obvious relation with the paths taken by the soil particles in passing over the plough: and the equation of these paths must clearly have some vital relation with the shape of the mouldboard and its efficiency. White recognized this last point and made some practical studies, while NICHOLS, in Alabama, and his associates have conducted extensive work on the behaviour of the furrow-slice in relation to the mouldboard shape. They arrived at a different general formula from White, as all their ploughs could be completely generated by arcs of circles moving along and rotating on, or directly above, the line of travel of the wing-tip.

This disagreement in formulae is not surprising. A short arc of moderate curvature can be fitted to a close arithmetical approximation by an exponential, or any conic section, even though its true equation is none of these; but the algebraic form of the generalized equation for the surface will, of course, depend on which basic equation is selected for development. If in these conditions an exponential, for example, is being sought, it is certain to be found, and found in all good faith, even if only because the discrepancies from a genuine exponential fall within the inevitable errors of experimental measurements.

At present, therefore, it cannot be said that investigators have discovered a generalized equation for mouldboard shape: an equation which, by straightforward and predictable alterations in the numerical values of the constants, would embrace all the various mouldboard shapes needed for different classes of work.

Further, the characteristics of the soil itself must enter into the equation, either explicitly or implicitly, for the response of the furrow-slice to the mouldboard curvature and to speed of ploughing must be affected by the soil plasticity, cohesion, moisture content, clay content, and so on. Nichols has done much pioneer work in the endeavour to bring in these factors, but the complex nature of soil introduces serious difficulties in both definition and measurement of such general properties as

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plasticity and cohesion. A further complication is that in soil cultivation we are concerned with soil at low to moderate water contents, whereas true plastic behaviour in the accepted scientific sense is shown only at higher moisture contents when the mix has reached the paste and slurry stages. Because of its importance in providing information on the physical and physico-chemical properties of the clay particle surface, much work on clay and soil pastes has been done at Rothamsted by SCOTT BLAIR and SCHOFIELD. Its discussion lies outside the scope of this article. However, it should be noted that their results and methods have already had important technical applications in such diverse directions as ceramics, oil drilling, synthetic plastics, and the preparation of flour-dough, butter, cheese, and toothpaste.

This work of Scott Blair and Schofield forms part of a wide programme of physical research on soil. Generalizations have grown up in soil physics, often based on simple experimental procedure, the results of which seemed to give a qualitative but plausible grouping of various soils into classes. The need for some such specification was as evident then as now, but it resulted in the appearance of many soil 'constants' and 'equilibrium points': most were empirical, some were spurious, others contained not one, but a complex of factors, and yet others depended on the subjective judgment of the experimenter. Part of the task of the modern soil physicist is to explore this collection and to reject, amend, or replace.

These so-called soil constants and equilibrium points fall into one or other of two classes. In one class, the soil and water are kneaded into a paste, and some property is measured on the sample: it may be the force for rupture of the dry block, the volume shrinkage of the block on drying, the lowest moisture content at which the sample can be rolled out without cracking, the moisture content at which it is just becoming sticky, or the moisture content at which the paste begins to flow when tilted. Measurements of this kind were developed and extensively used by ATTERBERG in Sweden in a system of soil classification, and they are of the kind that would naturally be used by agricultural engineers interested in the behaviour of soil towards cultivation implements of various types and designs.

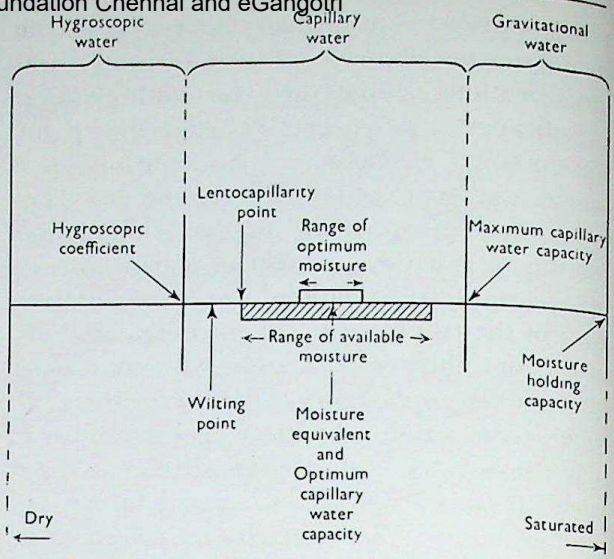

FIGURE 7 – *Diagrammatic distribution of some typical soil-water constants.*

In the second class the soil is used in its natural loose field condition (or in an analogous state of packing), when its pore space will be about 25 to 50 per cent., depending on the type of soil. This class of measurement attempts to specify the behaviour of the soil in natural conditions by a series of moisture contents corresponding to a series of prescribed environmental conditions. It is unnecessary to mention in detail the many measurements proposed and used; typical ones are set out in chart form in figure 7, which gives a general idea of their nature. Some had their origin in attempts to make an agricultural classification of soil types; others were devised in efforts to give some numerical specification of practical observations on soil conditions in relation to plant growth and the effects of cultivation operations.

During the period 1900-25 the development of these soil 'constants,' and the discovery of simple relationships between them, had a fascination for many soil investigators. It was, however, a dangerous occupation, especially for those who did not realize that the ease of making a particular measurement, and the straightforward reproducibility of the numerical result, were no guarantee that the figure expressed any real and simple physical property of the soil. Again, the existence of simple cross-relationships between two or more so-called independent constants was no proof that these constants had a simple physical

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interpretation. The primary objection to the incautious development of these constants and cross-relations is that they inevitably lead to classification schemes of the kind shown for soil moisture in figure 7. Superficially, this scheme is in accordance with the field behaviour of soil moisture, but as a foundation for the further development of a basic theory of soil-moisture relationships it is useless. Part of the trouble was that investigators took over from their predecessors without serious question the early theory of soil-moisture movement, based on the 'capillary tube' hypothesis. The theory was simple and attractive, and required no deep physical training for its understanding. Soil was porous, so the pore space could surely be regarded as a bundle of capillary tubes in which water would distribute itself in accordance with the simple concepts of surface tension and capillarity. It was admitted that the tubes must be irregular in cross-section, but it was convenient to assume that that could produce only minor discrepancies.

The essential feature of the phenomenon of capillarity is that the narrower the tube the greater is the height to which water will rise in it. At one stroke, therefore, the observed difference between drought-prone, coarse-grained, or sandy soils and drought-resisting, fine-grained, or clayey ones was explained. In the latter the capillary tubes were much narrower; they could draw up water from the underground water-table through much greater distances than sandy soils could. The traditional belief that hoeing conserved soil moisture had an equally facile explanation: hoeing disrupted the upper inch of the fine capillary tubes and produced a loose mulch with large pore spaces into which the water could not rise and be lost by evaporation. The agricultural operation of rolling young crops had also a simple explanation: the roll compressed the top soil round the young roots so that the narrower capillary tubes thus produced could draw water from the wider ones below for the benefit of the plant. It only remained for some numerical value to be put on the maximum effective height of capillary rise in typical soils and the practical demonstration of the theory would be complete. Laboratory and field experiments, however, showed rises of only 2 to 3 ft., instead of the confident predictions of 10 ft., 30 ft., or more—yet the theory still bore a charmed life.

The first hint that all was not well with it can be found in a paper, *The Dynamics of Soil Moisture*, written by BRIGGS in America as long ago as 1897. But he omitted an apparently unimportant step in developing his argument—a step which over thirty years later was recognized by HAINES at Rothamsted as the key to the problem. In 1917 VERSLUYS in Holland reopened the subject on lines which were correct although obscurely expressed. Later, at Rothamsted, Haines and then Schofield worked out the correct theory of moisture movement in soil and confirmed it experimentally. Haines showed that the pore space in soil was essentially of a cellular nature, consisting of relatively large voids communicating with one another through relatively narrow necks. The moisture distributes itself in curved films within these cells and necks in accordance with the physical principle that it tends to reduce its free surface, and hence its surface energy, to a minimum. The pressure under a curved water meniscus is less than outside, and the greater the curvature the greater is the pressure deficiency. The pressure deficiency, therefore, is a suction force which controls the filling or emptying of the cells.

The manner in which filling or emptying occurs can be seen by taking a simple case. Let a cell and its necks be full of water and suppose evaporation is taking place at one of the necks. The water level in this neck will retreat steadily, until the meniscus reaches the narrowest cross-section of the neck. Here the equilibrium becomes unstable, because further retreat of the meniscus carries it into a wider cross-section where a smaller pressure deficiency than the one already built up would be adequate to maintain equilibrium. Hence expansion into the cell takes place abruptly, or, in other words, air suddenly enters the cell and a portion of the water is displaced to new positions.

Similarly, when the moisture content is increasing from dryness to saturation, once the thickness and curvature of the water film lining the cell and necks attain a certain value, instability sets in. The films in one or more of the necks suddenly close; the stability of the

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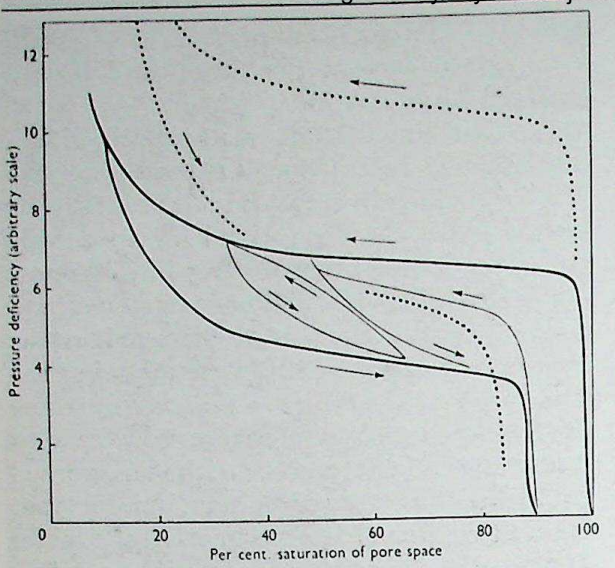

FIGURE 8 – *Haines' moisture content curves based on suction values. (Full curve: 'glistening dew'; dotted curve: sand.)*

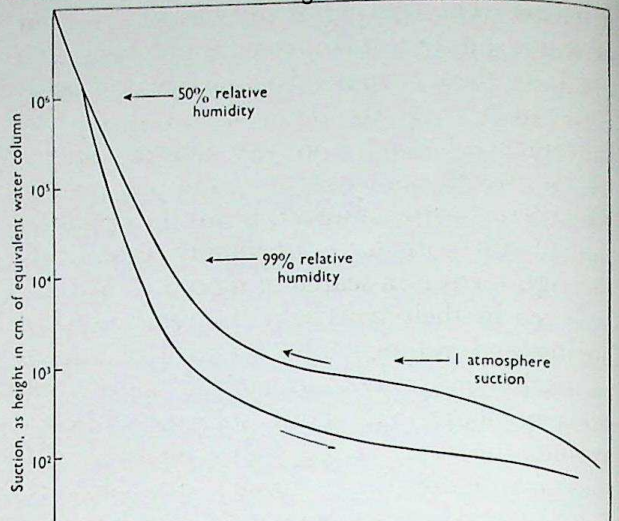

FIGURE 9 – *Schofield's moisture content curves based on energy relationships. (Soil: loam.)*

air bubble in the cell is upset and the cell becomes full of water. One salient feature of the moisture relations is, therefore, the quantum-like movements of water associated with filling and evacuation of the cells. But there is another important consequence of the theory: the opening and the collapse of a neck (and the emptying and filling of a cell) do not occur at the same pressure deficiency. There is no unique relation between pressure deficiency and moisture content. The relationship between them shows a marked hysteresis loop. Hence regions of high and low moisture content can exist in equilibrium together. Haines demonstrated the truth of this by simple and ingenious experiments. The hysteresis loops obtained for a mass of minute glass spheres and for sand are shown in figure 8. The drying curve lies wholly above the wetting curve. Hence the moisture content in equilibrium with a given pressure deficiency is higher if the soil is drying out than if it is being wetted. Again, by suitable cycles of drying and wetting the moisture content can be brought to any value within the hysteresis loop, as shown in the figure.

Haines' treatment of the problem is specially applicable to coarse, sandy soils. Schofield's later contributions produced a generalized physical theory based on energy relationships. Because it deals with energy relationships, this treatment has a great advantage: it is applicable to all soils and holds whatever the mechanism at work. Schofield expresses the differences in suction forces as free energy differences, which can be defined as the height in centimetres of the water column needed to give the suction in question. A logarithmic scale is used because of the wide range of this factor. Thus when the moist soil is in equilibrium with an atmosphere of 50 per cent. relative humidity ('air-dry' soil) the equivalent water column would be about 10 km. high, or higher than Mount Everest. By wetting and drying soils against suction and by using results for soil vapour pressures and freezing point depressions at different moisture contents, Schofield was able to obtain curves like the typical one shown in figure 9. The hysteresis loop is strikingly shown.

An important practical consequence of the hysteresis is that the water in the soil tends to resist changes, whether these are in the direction of increasing or decreasing moisture content. Instead of moving through the pores from regions of high moisture content to low, it will adapt itself to the suction gradient mainly by an alteration in the configurations and curvatures of the water films. To use an expressive Americanism, the water 'stays put'

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if it can. The bearing of this on the question of water supply to plant roots is obvious. The capillary theory taught that the drying due to water-imbibition by the roots was met by movement of water from the moister regions, i.e. the water was brought to the plant roots. The correct view, however, is just the opposite: the plant roots have to ramify extensively through the soil in search of moisture. We can now see in their true light the real effects of hoeing and rolling. The action of rolling is primarily the purely mechanical one of compressing loose but moist soil more closely around the roots of the young plant, so that they can more easily obtain the moisture. For any water movement of the type postulated in the capillary theory to take place, the soil would have to be so moist that no farmer would think of ordering the operation: the results on soil tilth would almost certainly be disastrous.

As for hoeing, there can be no general upward movement of water except in those cases of low-lying land where a water-table is very near the surface, and even then the rate of upward movement is exceedingly slow. In this case, as in the much commoner one where the water-table is well below the surface, the tendency of the water to resist changing conditions means, in effect, that it evaporates *in situ;* the dried-out surface layer progressively deepens. Most soils are, in fact, 'self-mulching,' and the use of a hoe to produce a soil mulch is, from the viewpoint of direct water conservation, a work of supererogation, except for those soils that tend to produce a hard crust or cap when drying. In these cases hoeing will break the crust in its incipient stages and so save the tender roots from damage. Of course, by destroying seedling weeds, hoeing prevents their competition for the available moisture and thus, indirectly, the operation conserves water.

The correct idea of soil moisture relationships, outlined above, enables us to form a clear picture of what happens to the rain when it has reached the soil. The soil is, normally, in the condition known as crumbs or compound particles. The crumb is an aggregate of soil particles, especially of the finest ones—the so-called clay fraction—which display this property of aggregation to a marked degree. The crumb itself is permeated by minute pores, much smaller than the pore spaces between

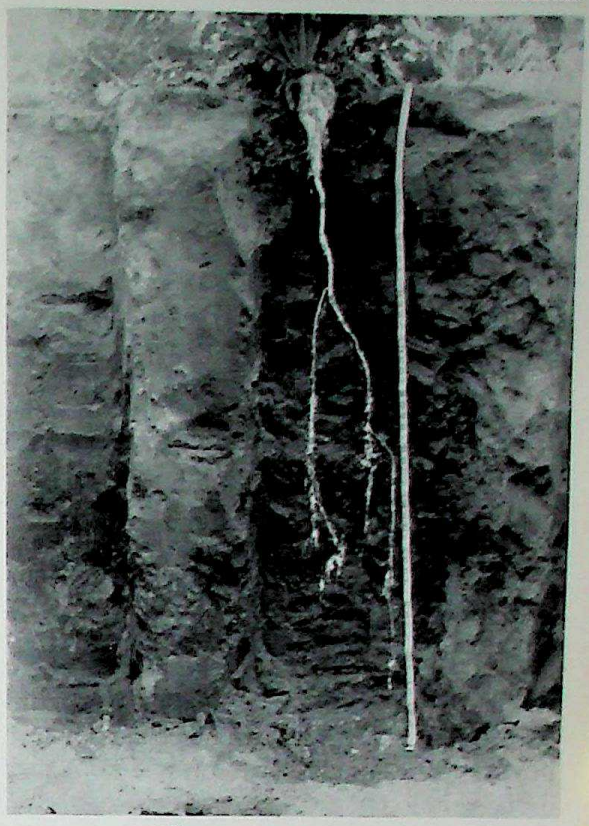

FIGURE 10 – *The root range of sugar-beet. (The tape is 5 ft. long.)*

the crumbs. If the soil is fairly dry and rain then falls, it enters the minute pores of the crumbs in the top layer. The excess rain passes downwards through the larger and cell-like pores between the crumbs and, in turn, each layer of crumbs levies toll on it. Depending on its amount and on the initial moisture content of the soil, the fate of the rain will fall between two extremes: it may be held wholly in the upper layers of soil—a frequent occurrence for summer showers—or it may displace water already in the soil, which percolates downwards until it reaches the water-table—a condition which is common in winter, when the pore spaces are practically saturated. Each soil crumb can be regarded as a minute water reservoir which, with any water left behind as a film in the bigger pores between the crumbs, is actively sought out by the exploratory root hairs on the plant's ramifying root system, which traverses its zone of growth so completely that the root hairs are never far away from a supply of moisture. This root system ranges much deeper than is generally thought,

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because few subsoils are so tight as to offer a complete barrier to the passage of roots and moisture. Studies of root behaviour made in America, and to a lesser extent elsewhere, show that the roots of common agricultural crops reach a depth of several feet: wheat, oats and sugar-beet, 5 to 6 ft.; barley, 3 to 4 ft.; and potatoes, 3 ft. Figure 10 shows a typical sugar-beet root in a light soil on the Lower Greensand formation. The excavation was 5 ft. deep, and at this depth the main root seen in the picture was still over $\frac{1}{16}$ in. (about 2 mm.) in diameter, and must have extended for at least another foot. Numerous subsidiary and lateral roots were necessarily removed during the digging. The water-holding capacity of the zone of soil traversed by plant roots is considerable. A 5 ft. depth of soil holds at least $7\frac{1}{2}$ in. of rain which, with summer rain, is ample for the transpiration needs of a good crop.

Modern science has shown, therefore, that cultivation operations have only a minor influence on the moisture regime of the soil and, in consequence, much of the traditional belief on this subject must be abandoned or recast. When these traditions are examined closely it is seen that although they embrace the three factors, cultivation, moisture, and plant growth, many are short-circuited into a direct relation between cultivation and plant growth. The gardeners' exhortation to 'keep the hoe moving among the crops' is a familiar example, and it is no exaggeration to say that most farmers believe that their crops will suffer by just the amount that their cultivations fall short of perfection. The belief was instinctive. The art of cultivation was well established long before agricultural science developed, and the practical man naturally felt that the operations were so obviously fundamental as to lie right outside any need for experiment. In settled countries innumerable field experiments have been made on artificial fertilizers and the number of such tests is still increasing, but experiments on cultivation were hardly ever made; yet the costs of cultivation are the heaviest single item in the arable farmer's budget and far exceed those for artificial manuring. In countries where agricultural development came later, experiments on cultivation were made, notably an extensive series in the Great Plains region of America, but the results were ignored in this country for the apparently adequate reason that as they were done in an area of low rainfall, the conclusions could not possibly apply to our own conditions.

Such was the position some dozen years ago, when cultivation experiments were begun at Rothamsted. Slowly but surely—all the more surely because it was against their preconceived ideas—the investigators were driven to the conclusion that crop yields were remarkably insensitive to variations in cultivation. All the experiments were full-scale trials: none can be dismissed on the grounds that it would not apply to practical field conditions. A variety of cultivation procedures was tested on different crops and in different seasons, and the work is still going on. The main results are briefly summarized in the next paragraph.

Subsoiling is a standby of many heavy-land farmers, but on the Rothamsted soil, which has a heavy clay subsoil, the operation produced no effect on sugar-beet. The normal preparation for root crops includes both autumn and spring ploughing, and if bad weather prevents the autumn ploughing some apprehension is felt as to the quality of the spring seed-bed; tests made with potatoes and sugar-beet as the crop showed that the double ploughing gave only an insignificant increase of yield over a single ploughing, and not nearly enough to pay for the cost of the extra work. Deep ploughing every year was no more effective than shallow ploughing, but there was slight evidence that an occasional deep ploughing gave a little increase in the yield of root crops. The nature of the seed-bed itself was also studied and it was found that it had little influence on the final yield. Many experiments have been done on the inter-row cultivation of root crops, in which the minimum hoeings necessary to keep down the worst of the weeds have been compared with a greater number of hoeings. For a number of years the result of the extra hoeings was either no increase in the crop or, more often, a significant reduction in yield, a result due in all probability to the inevitable damage done to shallow-feeding roots. In some of the later experiments on inter-row tillage an increased yield was sometimes obtained. The design of the experiments enabled this positive effect to be traced to one hoeing done in the early stages of plant growth,

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and the effect has been confirmed in experiments on another type of soil. It suggests that farm and garden crops are specially sensitive to weed competition in the early stages of their growth and that one hoeing then is worth many afterwards.

The net result of all this work is to show that, provided the crop has a reasonably fair seed-bed, that it is given a hoeing in its early stages, and that the worst of the later weeds are kept down, then any cultivation of the soil—whether before sowing or during growth—in excess of this minimum is of little direct value to the plant. The results are in harmony with those reached by the investigators on the Great Plains area, and they are in harmony with modern knowledge of soil physics. They are in conflict with a deeply ingrained tradition, which had at least three apparently sound reasons behind it, as well as the capillary theory. The first of these reasons was that until the Industrial Revolution provided the farmer with good implements he fought a losing battle against weeds: cultivation at every available opportunity was his only hope. The second reason was that cultivation in the early stages of plant growth sometimes produces striking results, and it was assumed that the yield would benefit correspondingly; the Rothamsted experiments have occasionally shown similar effects which have, however, disappeared by harvest time, so that the ultimate criterion—yield—has not been affected. The third reason was that keen and successful farmers were, almost invariably, enthusiastic exponents of the art of cultivation. This was perhaps the most cogent argument of all to the average farmer: surely these leaders' farms and bank balances proved that their views were correct. But the real reason for their success lay not in the artistry of their cultivations, but in another quality, for which a traditional reason also exists: 'the master's footsteps are the best manure for his land.'

If the present article had been written twenty-five years ago, when the vast majority of cultivation implements was horse-drawn, the results of the cultivation studies now discussed would have had little more than academic interest. A horse costs nearly the same to keep whether he is working or idle, so the real cost of cultivations was negligible. But now, few farms are without a tractor, and the bulk of all cultivations is done with power-drawn implements. A tractor, properly looked after, does not cost anything when idle, and the more it works the higher is the fuel and oil bill. There is, therefore, a powerful economic reason to reinforce the scientific arguments for a complete and critical examination, on all types of soil, of our cultivation methods.

Sir William Bragg, O.M.

It is with deepest regret that we record the death, on 12th March, of SIR WILLIAM BRAGG, O.M., K.B.E., F.R.S., doyen of British physicists, and universally celebrated for his brilliant investigations upon the minute structure of matter. Bragg was born on 2nd July, 1862, and was educated at King William's College, Isle of Man, and Trinity College, Cambridge, where in 1884 he was Third Wrangler. From 1886 to 1908 he held a professorial chair in the University of Adelaide, afterwards becoming Cavendish Professor at Leeds University (1909–15) and Quain Professor of Physics in the University of London (1915–23). In 1904 and following years he showed that the α-rays from different radio-active substances went different distances through different media, and that their range was closely connected with the atomic weights of the atoms in the medium penetrated. He also carried out work on β-rays and on X-rays, and examined the corpuscular properties of the latter. Later, he collaborated in the experiments of his son Sir Lawrence Bragg on crystal structure, and the results of the partnership were of such importance that father and son were jointly awarded the Nobel Prize for Physics in 1915. Sir William also received the Rumford Medal (1916) and Copley Medal (1930) of the Royal Society, and was honoured by universities and learned societies in all parts of the world. His death is a heavy blow to British science, which it deprives at once of a great investigator and a great administrator. One of his last acts was to further with enthusiasm the launching of ENDEAVOUR, to the inaugural number of which he contributed.

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The significance of metal single crystals

E. N. da C. ANDRADE

In this article Professor Andrade describes some of the remarkable properties of individual crystals of metals, a subject upon which he himself has carried out fundamental investigations. It may seem a far cry from a single crystal to the foundry, but Professor Andrade shows that some of the most valuable industrial qualities of metals are a function of the qualities of their constituent crystals.

One of the most striking properties of metals, as contrasted with solids of many classes, is that they can, under suitable conditions, be very considerably deformed without rupture, a property denoted by the rather ill-defined term 'plasticity.' On this property are based the industrially fundamental processes of forging, drawing, rolling, extrusion, and such-like, which were carried out for centuries without any systematic inquiry as to the structural interpretation of the changes taking place. In 1864 SORBY initiated the study of metallography, but it was not until 1899 that EWING and ROSENHAIN drew attention to a change which plastic deformation of a metal could produce in the crystallites of which the metal is composed. There appeared in these crystallites systems of parallel lines or ridges, which they attributed to slip along the 'cleavage planes' of the minute crystals. This discovery should have indicated the importance of investigating the behaviour of single crystals of metals under definite conditions of stress, but it was not until 1914 that suitable test pieces, namely thin rods, were more or less accidentally prepared, in which the crystal axes were the same throughout—that is, the rods were metal single crystals in which the external crystallographic faces were not developed, but replaced by an arbitrary cylindrical boundary, just as the external faces of a cut diamond are arbitrary. In the interval between the end of the last war and the beginning of the present war extensive investigations have been carried out on the mechanical properties of such monocrystalline specimens, mainly in England, Russia, and Germany. For some reason the subject does not seem to have attracted American investigators.

Most of the experiments have been carried out by the extension of rods or stout wires in which the single crystal structure has been produced by one method or another of slow growth from an initial crystal 'seed,' although important results have been obtained by G. I. TAYLOR on stouter specimens subject to compression and by CARPENTER and ELAM working with flat specimens. Some of the properties found can be easily reconciled with well-established ideas. For instance, the permanent extension of the crystal specimen takes place by slipping on certain preferred crystalline planes and in a certain preferred crystallographic direction[1]. This seems reasonable, although it can produce queer-looking results when a crystallographically unique glide plane happens to be nearly at right-angles to the axis of the wire, as shown in figure 1, which represents a cadmium wire with the hexagonal basal plane vertical, as the picture is arranged on the page. Tension along the wire has produced considerable slip across the direction of tension, to the left, and a lesser slip on another plane towards the extreme right.

Less easily reconciled with familiar ideas is the fact that, in general, slip does not take place equally on all parallel planes, but more especially on certain arbitrary ones, giving a characteristic appearance of a set of layers, as seen in figures 2 and 3. The spacing of the layers

[1]The direction is more fundamental than the plane and is always atomically the most closely packed direction. See E. N. da C. Andrade, *Proc. Phys. Soc.*, 1940, **52**, 1.

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varies from metal to metal, and also with temperature. It may be as small as 1 μ—but even this is about 3,000 crystal plane spacings—or as large as 1 cm. A general rule is that the higher the temperature the wider the spacing. The existence of these 'glide lamellae' points to a lack of ideality in the crystal behaviour, since with a perfect crystal a uniform distribution of glide might be expected. Further, it has been established that if the crystal is left under a suitable load the slips take place in small jumps at discrete intervals of time. Thus the phenomenon is discontinuous in both space and time. We are confronted with small local avalanches.

Other striking general properties of single crystals are their yield under very small forces, and, especially in certain cases, the very large plastic extensions that can be produced without rupture. There are strong theoretical reasons for supposing that the yield point of *perfect* crystals should be much higher than that found for any industrial metal, and the fact that industrial metals do not reach their theoretical limit was sometimes in the past put down to their polycrystalline structure. Actually, however, a metal in single crystal form is much weaker than the same metal as ordinarily found: single crystals show plastic yield under stresses about one hundredth of those given as the tensile strength for the polycrystalline metal. As regards extensibility, single crystals of cadmium, for instance, can be drawn out to as much as five times their original length, the cylinder becoming, on account of the glide in a fixed direction, a flat ribbon. Figure 4 shows this ribbon effect, the marked slip having started to take place, for reasons that would take us too far, on a fresh set of planes where the sudden thinning occurs. Normal to the paper the specimen is equally thick all along.

A further feature of single crystals is the remarkable hardening which they show under large strain, corresponding to the so-called 'work-hardening' of ordinary metals. This is particularly striking when the metal is far from its melting point, and thus, if experiments are done at room temperature, it is strongly shown by metals of comparatively high melting point, e.g. silver, gold, and copper, rather than by lead and zinc. To take an extreme case, it is on record that, with a single crystal of silver, an extension to something over double the original length produced a ninety-two-fold increase of strength.

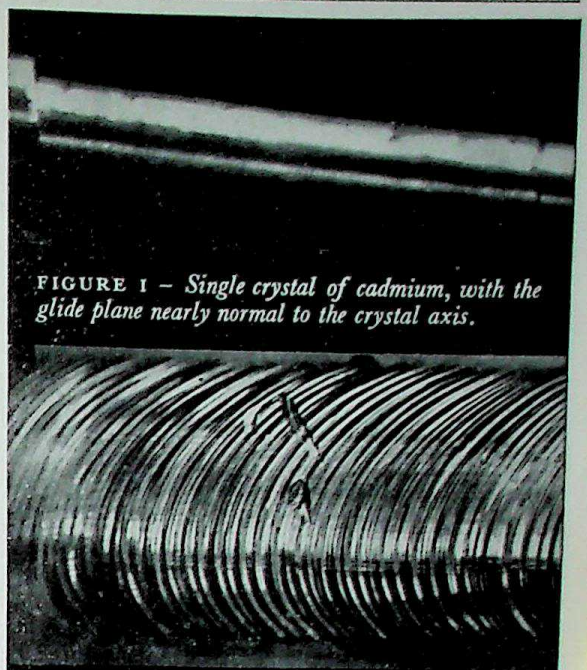

FIGURE 1 – *Single crystal of cadmium, with the glide plane nearly normal to the crystal axis.*

FIGURE 2 – *Single crystal of solid mercury, showing glide lamellae.*

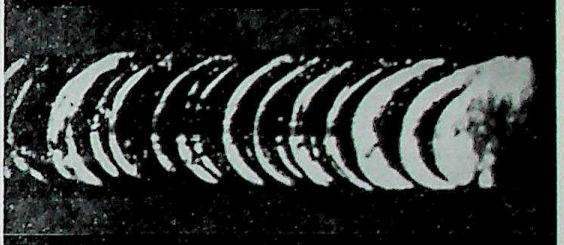

FIGURE 3 – *Single crystal of molybdenum, showing glide lamellae.*

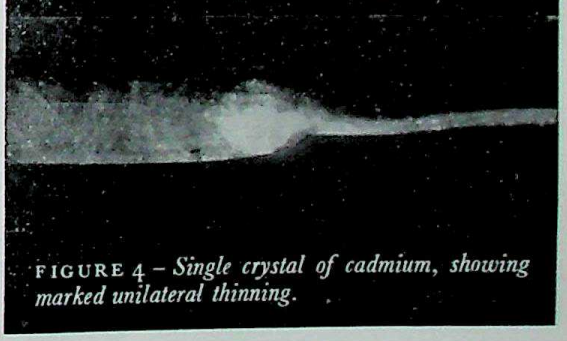

FIGURE 4 – *Single crystal of cadmium, showing marked unilateral thinning.*

We are confronted, then, with the paradox that a single crystal, which might be expected to be very strong, suffers plastic deformation under quite small stresses, but, if the temperature be such that 'crystal recovery' does not

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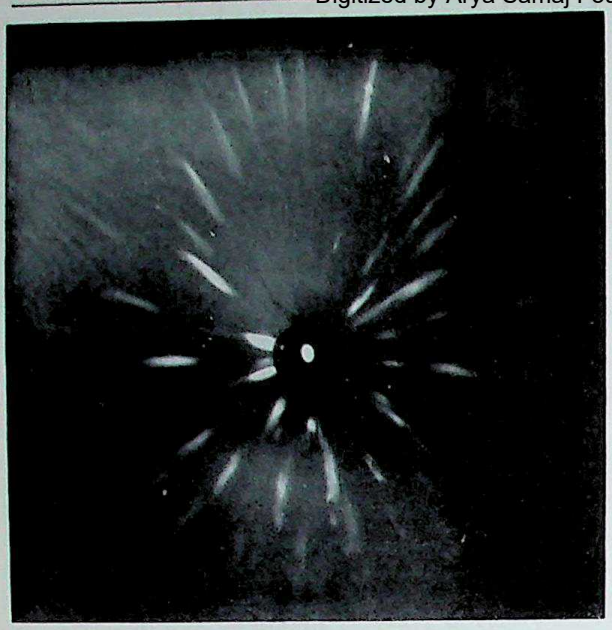

FIGURE 5 – *Laue spots, that should be more or less circular for a perfect crystal, drawn out into asterisms in the case of an iron crystal extended by* 16 *per cent.*

take place, hardens considerably as the deformation proceeds. It can be shown by the use of X-rays that the increasing strength is accompanied by a local break-up of the crystal lattice: the Laue spots, which approximate to small discs in the case of a good crystal, are drawn out into smears or 'asterisms' as shown in figure 5. These general features do not seem capable of explanation on the assumption that single crystals, as prepared, are built on a perfect lattice. Temperature agitation cannot be invoked as the fundamental cause of plasticity because, surprisingly enough, single crystals of cadmium show great plasticity even at only 1° C. above absolute zero.

The only theories that seem to offer even a partial solution of the problem are based upon the supposition that the crystal lattice is not perfect, but contains places of misfit, where the atoms find themselves 'out of step' with their neighbours. It can be shown that at such a spot a shear stress is likely to cause an avalanche-like glide running along the crystal plane. A very imperfect analogy is provided by the way in which a small cut in the edge of a fabric makes it easy to tear, the tear running along a structural line. Thermal agitations may from time to time conspire to cause local conditions particularly favourable to the glide, which accounts for the discontinuity in time of the avalanches. How the places of misfit originate, and whether they are inevitable, is not known. It may be that they are a kind of 'frozen Brownian movement,' and are bound to be formed when a metal solidifies from the melt.

The hardening is closely connected with the considerable disturbances of the structure that the strain itself produces. At higher temperatures these can heal themselves: we have 'crystal recovery' and little hardening. At lower temperatures they are more or less permanent. Probably the courses of the avalanches are stopped by the artificial breaks created in the structure, just as there seems little doubt that they are stopped by the crystal boundaries in a polycrystalline metal, which accounts for its superior strength.

The study of single crystals has brought to light a series of strange phenomena which, it seems clear, originate in the departure of the actual structure from an arrangement on a perfect lattice. At certain more or less regularly distributed spots the regular order is broken: there are 'dislocations,' which may be inherent in crystal structure. These, as potential origins of glide, are the source of the strange softness of an unstrained single crystal, a softness which rough handling remedies, probably by the creation of what are virtually crystal boundaries where the regular structure is broken. The dislocations may be looked upon as plague-spots from which epidemics may be rapidly propagated: at the boundaries there are quarantine stations which prevent the infection spreading. From the point of view of the practical metallurgist we have two tasks: firstly to see if the disease centres can be stamped out or diminished and, if not, to see how the boundaries can be made as frequent as possible and the quarantine as effective as possible. Single crystals in themselves may seem remote from the foundry, but they carry in them the secrets of metallic softness and strength.

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The Museum of the History of Science, Oxford

F. SHERWOOD TAYLOR

The development of science resembles the growth of an organism, and properly to understand its present or to estimate its future we need to have as complete a knowledge of its past as is possible to obtain. The paraphernalia of bygone scientists form an integral part of this knowledge. Dr Sherwood Taylor reveals some of the wealth of such historic equipment preserved in the Old Ashmolean building at Oxford.

Science, readier to anticipate the future than to recall the past, has had small regard for relics. Little historic apparatus has survived, and it is well that the Museum of the History of Science should be wholly devoted to these heirlooms of natural philosophy, and should continue to house them in a building which is itself a monument to the scientific zeal of a bygone age. In the revival of science which preceded and followed the formation of the Royal Society, no country took a greater part than England, no place than Oxford. BOYLE, HOOKE, MAYOW, LOWER, WALLIS the mathematician, WILLIS the anatomist, HALLEY the astronomer, all carried out some part of their researches at Oxford, and much of the early *Philosophical Transactions* was printed there. Need was felt for a home of science in Oxford, and the opportunity was made by ELIAS ASHMOLE, fervid if credulous lover of learning. Ashmole had come into possession of the collection of rarities made by the brothers TRADESCANT, and presented these to the University on condition that a home was made for them. So in 1683 the 'large and stately pile of squared stone,' shown in figure 1, was completed. The magnificent portal led into a pillared hall—the School of Natural History; above it was the Musaeum Ashmoleanum; below it a stone-vaulted chemical elaboratory, which today shelters our collections from air attack. There was also a library which once possessed the priceless Ashmolean collection of manuscripts, now in the Bodleian. DR PLOT, author of *The Natural History of Oxfordshire*, became the first curator. Ashmole's high hopes for the institution were not altogether realized. The

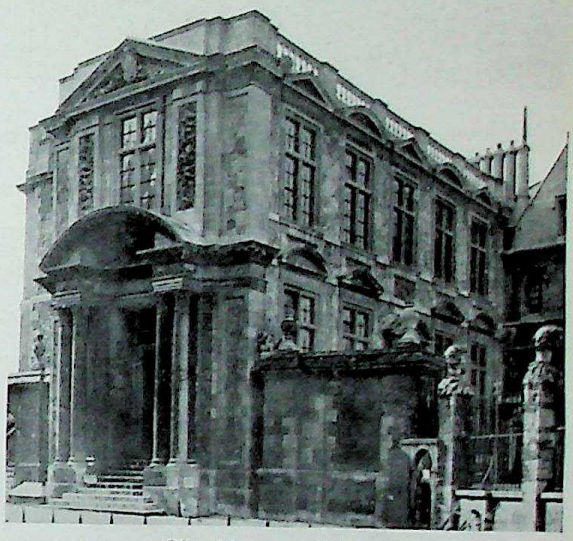

FIGURE 1 – *The Museum of the History of Science.*

collections were preserved and augmented, but in eighteenth-century Oxford science sank into a lethargy. Enthusiasts were few and it was then that the museum committed its major scientific crime of destroying the two stuffed dodos, because, forsooth, they had become somewhat dilapidated.

With the nineteenth century, science in Oxford revived, but the Ashmolean building proved neither large enough nor adequately equipped for modern science. The laboratory and the scientific collections were removed, and the archaeological collections and the title of Ashmolean Museum were transferred to a building in Beaumont Street. Ashmole's noble building was devoted to housing the scholars who made the great *Oxford Dictionary*. But in 1925 science returned to its home. LEWIS EVANS, learned and

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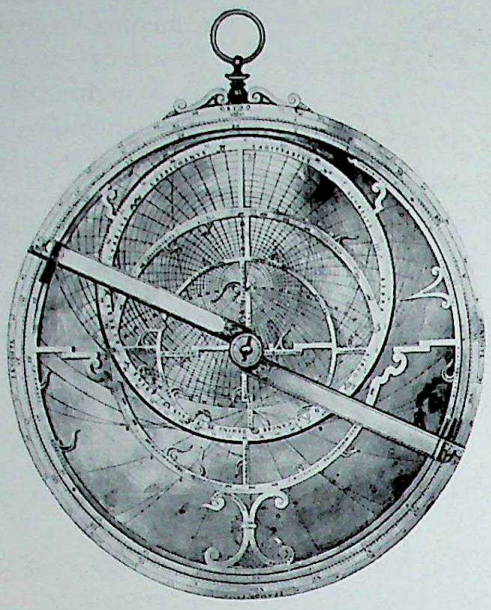

FIGURE 2 – *Astrolabe of F. Egnatius Dantes, in gilt brass. About* 1580.

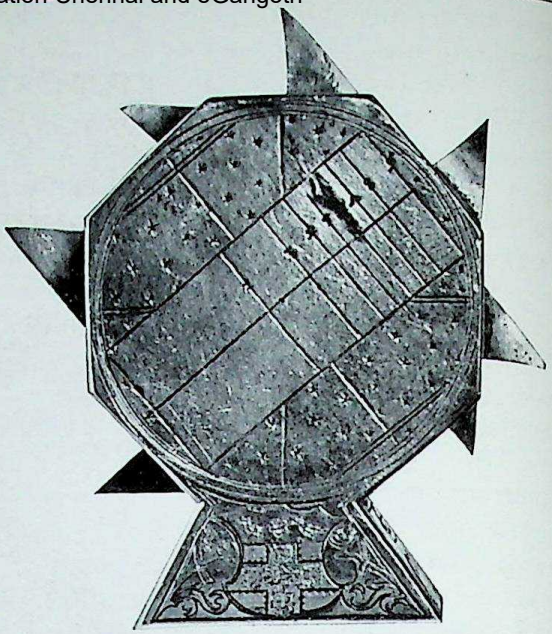

FIGURE 3 – *Block dial made for Cardinal Wolsey by N. Krätzer.*

indefatigable collector of astrolabes, dials and the like, presented his collection to the University, as did Ashmole before him, on condition that it was suitably housed. The collection, augmented by loans and gifts from the colleges and many other sources, was housed in the old Musaeum Ashmoleanum until the outbreak of the present war: after the war, if no evil befall, it is to occupy the whole of this superb building.

The collection ranges over the whole field of science from the Arabs to the twentieth century. Its most remarkable feature is its series of astrolabes. The astrolabe (figure 2) is, briefly, a graduated circle, furnished with sights for taking the altitude of the sun or a star, and a projection of the heavens, by aid of which the time of day and other conclusions can be deduced from the altitude without calculation. Invented by the Greeks, astrolabes were the most important astronomical instruments of the Middle Ages. They were owned not only by philosophers, but by princes, shahs, sultans; no beauty of ornament or skill of craftsmanship was thought too great for them. The same ingenuity and art were lavished upon sundials, and upon nocturnals, which measure time by the wheeling of the Bears about the Pole. The design of dials was a recreation of the geometer, and their ingenuity presents some problems to the modern collector. Our most interesting dial is that made for CARDINAL WOLSEY by KRÄTZER (figure 3), who is thought to be responsible for the Hampton Court clock.

Such men as Boyle and Hooke left few relics. The apparatus of working laboratories rarely survives, for its fate is to be pulled to bits and made into something else. The scientific instruments which achieve the Elysium of a museum case are those bought by rich amateurs, handled a few times, then relegated to a peaceful cupboard for a century or so. Such was the fate of one remarkable collection of instruments which reached our museum. CHARLES BOYLE, fourth Earl of Orrery and great-nephew of Robert Boyle, amassed in the years round 1700-10 a collection of philosophical instruments and bequeathed them to Christ Church, where they seem to have remained almost untouched till 1919. They are now on loan to the museum and preserve for us a collection of the finest work of the instrument-makers of the day, untouched by the fell hand of the renovator who has added later improvements to so many ancient instruments. Out of some fifty items may be mentioned a superb microscope by JOHN MARSHALL (1704), an exquisitely finished model of the Copernican sphere, and several telescopes.

The earliest astronomical telescopes were of wood, while terrestrial ones were usually of vellum, for until the eighteenth century was

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well under way it was not possible to make brass tubes to slide sweetly one within the other. The vellum telescopes are very beautiful, their outer cases tooled in gold and stained in soft reds and greens. They are also very light but, of course, lack rigidity. Oxford's observatories, the Savilian and the Radcliffe, have left us many noble instruments, and very notably the great eight-foot quadrant of JOHN BIRD, the high-water mark of eighteenth-century instrument-making.

The museum is rich in orreries—mechanical models of the solar system, which were invented by the instrument-maker ROWLEY and named after his patron the fourth Earl of Orrery. We have not the original orrery, but we have on loan three which are of the first interest both as instruments and as objects of art. The grand orrery from All Souls College (figure 4) not only shows the motions of sun, moon, and planets, but also those of the numerous satellites of Jupiter and Saturn. Microscopes progressed greatly in the eighteenth century, but space allows me to single out but one of our collection, which presents the eighteenth-century idea of a king's microscope. The collaboration of silversmith and instrument-maker produced the magnificent instrument shown in figure 5, absurd but a type of a bygone age.

FIGURE 4 – *Grand orrery by Heath and Wing; lent by All Souls College, Oxford.*

Old chemical apparatus is very rare, for glassware continues in use till it is broken. Yet in the museum is an appreciable part of the apparatus which was used in the old public elaboratory a century and more ago. Glass alembics differing not at all from those used in the Middle Ages, and a collection of miscellaneous apparatus, eudiometers, U-tubes, combustion tubes, a charcoal tube-furnace and so on, form a remarkable exhibit. A very large burning-glass on an elegant stand reminds us that the sun provided the only heat greater than that of a wind furnace. Of chemicals, we possess three cabinets of materia medica, containing many hundreds of named specimens of eighteenth-century drugs, including such items as the skeletons of vipers and black pitchy-looking mumia—dried human flesh. But perhaps the most significant of our chemical exhibits is the germ of a vast industry in the form of an elegant lignum vitae cabinet, lined with red velvet, containing a dozen or so of handsome bottles. A silver plate proclaims that it contains: 'Products obtained from coal according to the PROCESS of Mr. Winsor, prepared by T. Accum, Lecturer on CHEMISTRY in the Surrey Institution.' ACCUM was at this institution between 1803 and 1819. The bottles contain muriate of ammonia, carbonate of ammonia, and a number of products derived from coal-tar. One of these, 'Highly Rectified Essential Oil,' can be nothing else than benzene, prepared a good many years before FARADAY's discovery of it in 1825!

Air-pumps, electrical machines, surgical instruments, barometers, thermometers, dumbly demand description which space unfortunately forbids.

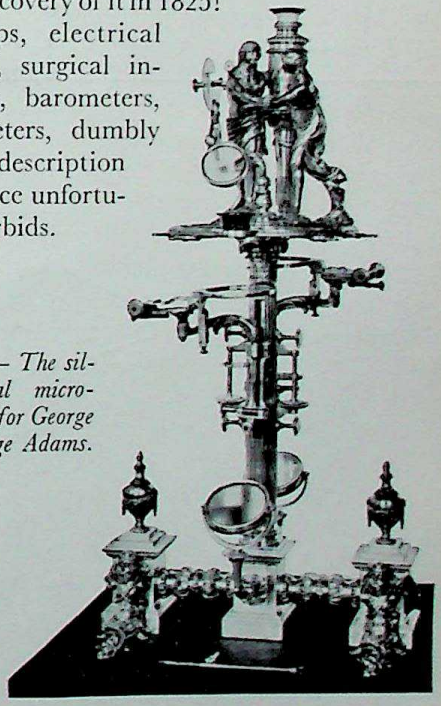

FIGURE 5 – *The silver universal microscope, made for George III by George Adams.*

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Textile fibres under the X-rays

W. T. ASTBURY

Not so long ago, elucidation of the structure of textile fibres would have seemed an unrealizable scientific ambition. Dr Astbury is able to demonstrate not only that the problem is by no means insoluble but that, in fact, it has already been largely solved. His original X-ray photographs, with their explanatory text, indicate the line of approach—and explain, incidentally, the scientific basis of the 'permanent wave.'

X-ray structure analysis is a wide subject, but it is still rather a specialist's subject. A grasp of its principles, nevertheless, and an appreciation of its many applications are within reach of all who are trying to advance or apply physico-chemical and biological knowledge. Some of the most fruitful developments in recent years have been in the field of textile and other biological fibres. Natural fibres are found to be constructed very much as textile yarns are constructed from the fibres themselves, only Nature uses long chain-molecules instead. These run along the length of the fibre, or spiral-wise round it, in thin bundles that are in effect submicroscopic crystallites of the fibre substance. The size, shape, orientation in the body of the fibre, and ultimately the intimate molecular structure of the invisible crystallites, are all susceptible of study by X-ray methods, as will be seen best from the examples illustrated and briefly discussed below.

The experimental technique of X-ray fibre analysis is again relatively simple in principle —it is the correct interpretation that calls for the nicest co-ordination of mathematical, physical, chemical, and biological data—and the gist of it will be clear from figure 1. The X-rays are directed in an approximately parallel beam, say ½ mm. thick or less, by means of a cylindrical channel, or 'slit' as it is loosely called, down the centre of a heavy-metal tube some centimetres long, or by means of pinholes in two lead plates. Immediately in front of the slit, and generally perpendicular to the X-ray

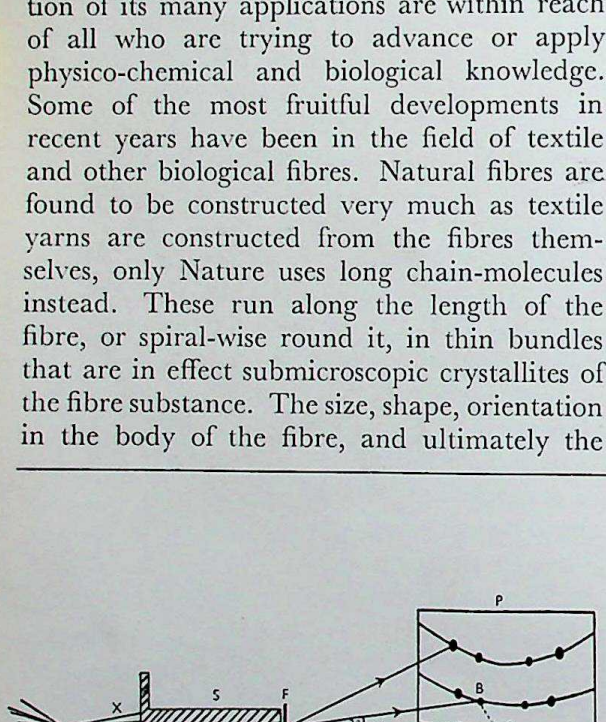

FIGURE 1 – *Illustrating the diffraction of X-rays by a rotating crystal or a bundle of parallel fibres.* A, *anticathode of X-ray tube;* X, *X-rays;* S, '*slit*'; F, *fibre bundle;* OC, *incident undiffracted beam;* OB, *a diffracted beam;* P, *photographic film;* C, *lead cup and centre of photograph.*

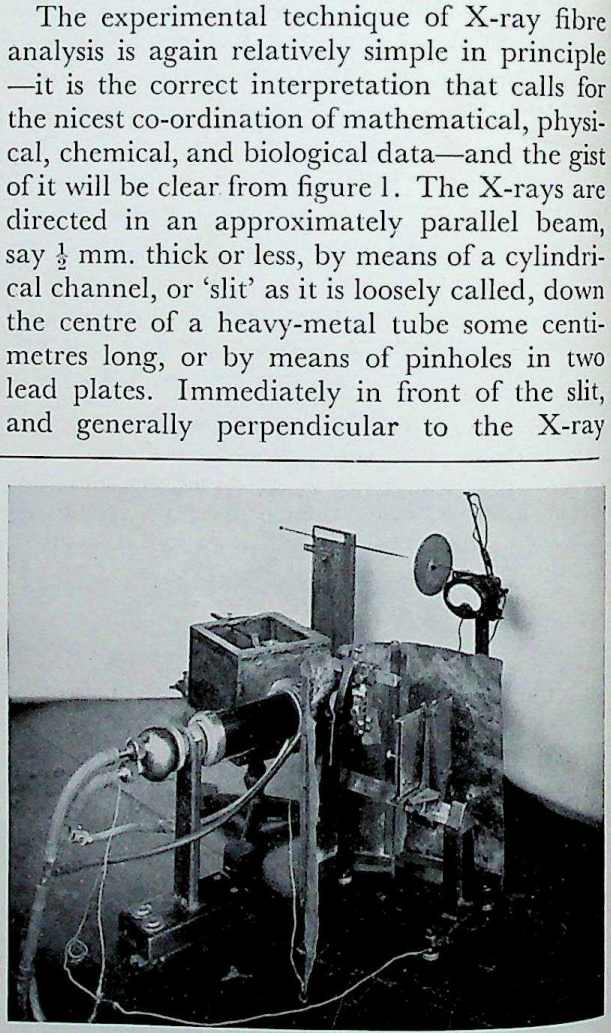

FIGURE 2 – *An X-ray tube with an X-ray spectrometer set up at each window.*

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beam, is mounted a small parallel bundle of the fibres under examination, while a few centimetres beyond the fibres is mounted the photographic plate or film, suitably protected from light by black paper or thin aluminium foil (which the rays penetrate fairly easily). The fibre crystallites 'diffract' the incident beam in directions depending on their form, mutual arrangement and molecular structure, and the diffracted beams give rise, on developing the photograph in the usual way, to a pattern of *black* 'spots' or arcs distributed, in the ideal case, along a series of co-axial hyperbolae. Figure 2 is a view of two actual X-ray spectrometers (of different types) set up one at each window of an X-ray tube.

X-rays are short-wave light for the eyes of the mind, so it is important for the lay reader to realize that the pictures shown here do not represent anything that can be seen by the human eye, even with the aid of the microscope: they are 'diffraction patterns' arising from the way the atoms and molecules are arranged. The shape and dimensions of the fibres themselves mean almost nothing: we are looking *inside* where the essential physical and chemical properties reside.

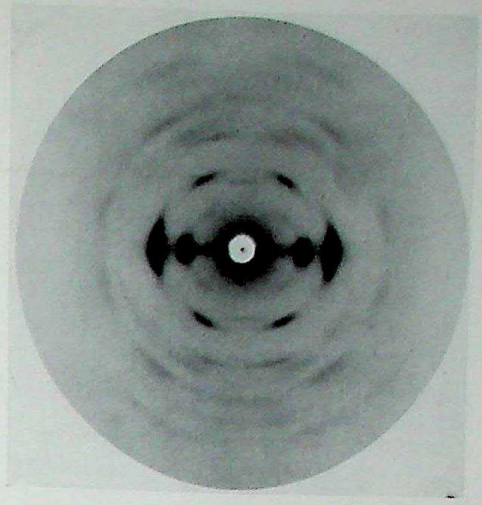

FIGURE 3

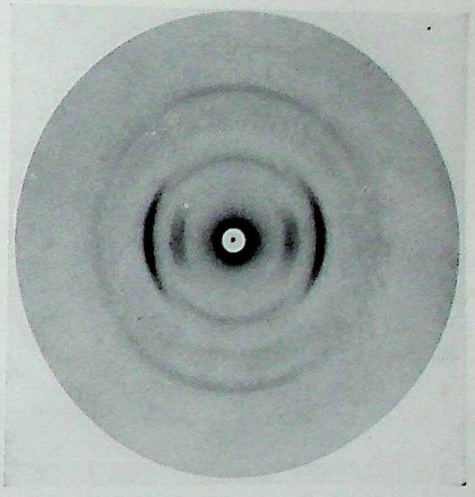

FIGURE 4

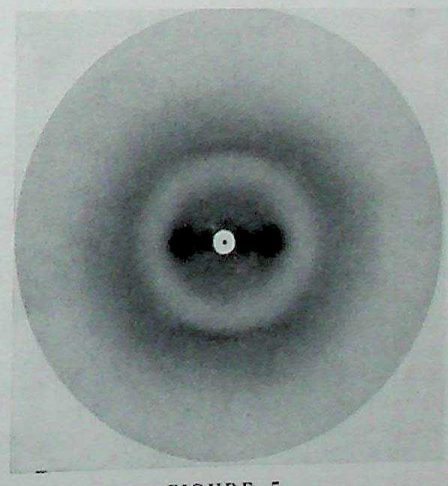

FIGURE 5

Figure 3 – The natural fibre *ramie*, made from the polysaccharide cellulose, the molecules of which are long chains of β-glucose 'residues.' From photographs such as this it has been possible to determine the form of the cellulose molecule almost completely. Notice the broad 'spots' on or near the equator of the photograph as compared with the sharper spots on or near the meridian, which means that the crystallites are long and thin—regular chain-bundles, in fact. A similar effect will be seen in most of the other photographs and for a similar reason.

Figure 4 – *Cotton*, also built from cellulose chain-molecules, but this time laid down in pronounced spirals round the fibre axis, as is shown by the spots being drawn out into arcs.

Figures 5, 6, 7, 11 (*a*) *and* 11 (*b*) – All the wools and other mammalian hairs, nails, horn, hooves, spines, whalebone, etc., give, when unstretched, the pattern shown in figure 5, which is that of the protein α-*keratin*. When stretched they give the pattern shown in figure 6 (β-*keratin*), but when they are allowed to contract again to their original length the α-pattern returns. X-rays thus reveal a reversible transformation of the keratin molecules themselves and explain in this way the beautiful long-range elastic properties of hair, as also those of muscle, the chief protein of which, *myosin*, gives

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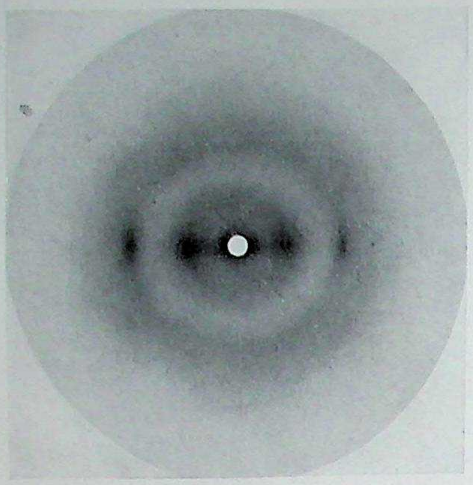

FIGURE 6

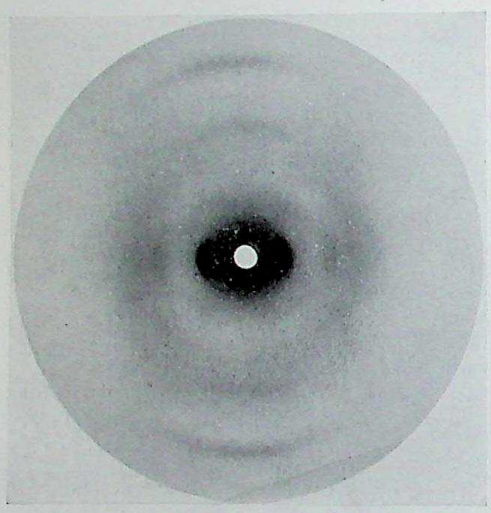

FIGURE 8

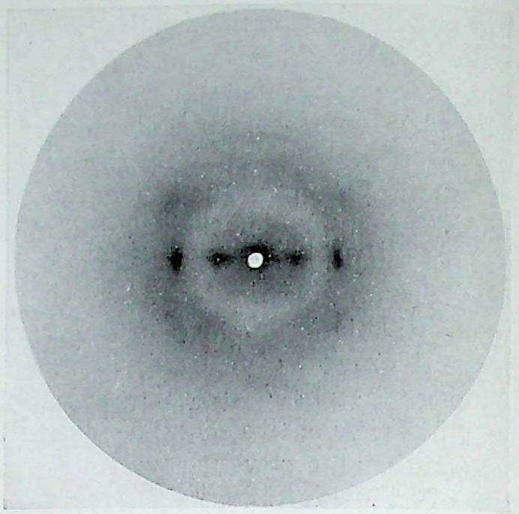

FIGURE 7

X-ray patterns of the same type. The α-form of keratin and myosin is built from regularly folded polypeptide chains which straighten out when the specimen is pulled, then return to their original folded form when it is released. By a development of this interpretation it is possible to explain also the 'setting' of hairs stretched or deformed in hot water or steam, and hence the 'permanent wave'! Figure 7 is the X-ray pattern given by human hair stretched in steam. Figs. 11 (*a*) and 11 (*b*) are X-ray micro-photographs of a single hair, unstretched (*a*) and stretched (*b*). They are the same as figures 5 and 6, only on a much smaller scale because of the special technique involved. A recent case in which X-ray single fibre photographs found a noteworthy application was an investigation of the very rare abnormalities of human hair known as *Monilethrix* and *Pili torti*.

Figure 8 – A parallel bundle of fibres from untanned cow-hide (*collagen*). The collagen fibres include connective tissue, tendons, fish skin and fins, cartilage, gelatin, etc. Leather consists almost entirely of disoriented collagen fibres. Common to the whole group is a characteristic diffraction pattern which has been interpreted as arising from polypeptide chains in a partial *cis*-configuration, as opposed to the slightly longer *trans*-configuration in silk and stretched keratin. Changes in the collagen diffraction pattern give valuable information in the study of tanning and similar phenomena.

Figure 9 – Natural silk (*Bombyx mori*). X-rays show that this fibre (the protein *fibroin*) is built from fully extended polypeptide chains. Like cellulose, it has therefore no long-range elasticity of the type shown by hair and muscle.

Figure 10 – The quill of a seagull's feather. A pattern of this kind is common to all feathers and beaks of birds, tortoiseshell, reptiles' scales, etc. It lays bare in a strikingly fundamental fashion the phylogenetic affinity of birds and reptiles as distinct from the mammals.

Figure 12 – An artificial silk, or *rayon*, made from regenerated cellulose. The chain-molecules lie side by side just a little differently from what they do in native cellulose fibres. The occurrence in the photograph of so many and such sharp spots instead of arcs is a measure of the perfection and strength of this particular rayon.

Figure 13 – *Nylon*, the new and truly synthetic fibre (a polyamide) that is now rivalling natural silk. It is a plastic, the fibres or bristles being spun from the molten state.

Figure 14 – The mineral fibre, *chrysotile asbestos*. It is a silicate (a fibrous serpentine) constructed from long chains of linked (SiO_4) groups. The fact that certain spots are drawn out into streaks along the hyperbolae shows that the sideways distance between the chains is variable, on account of variations among the metallic ions that lie between them and hold them together.

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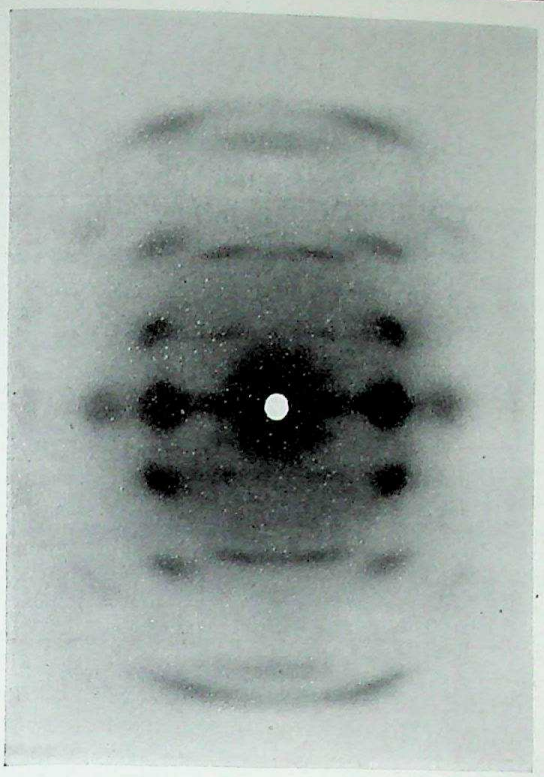

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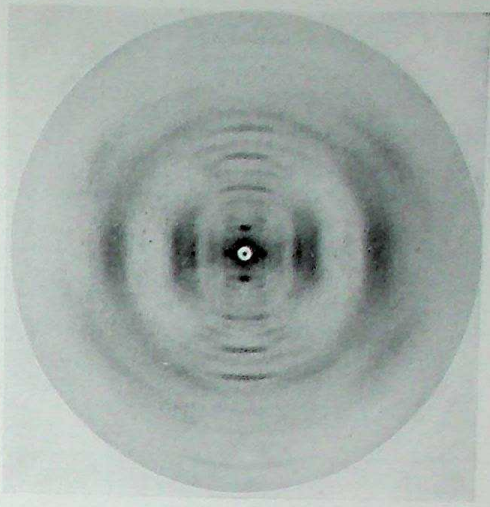

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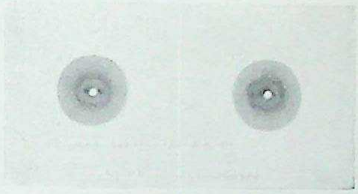

(*a*) (*b*)

FIGURE 11

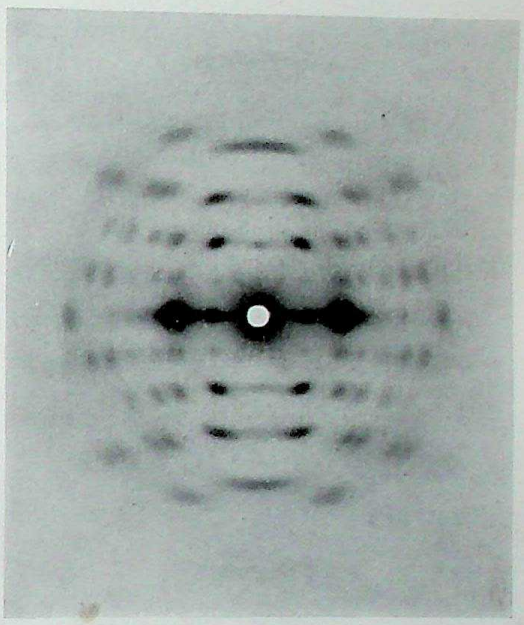

FIGURE 12

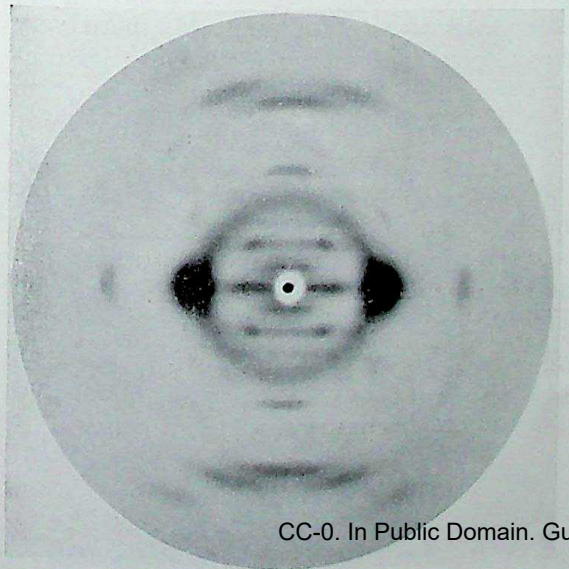

FIGURE 13

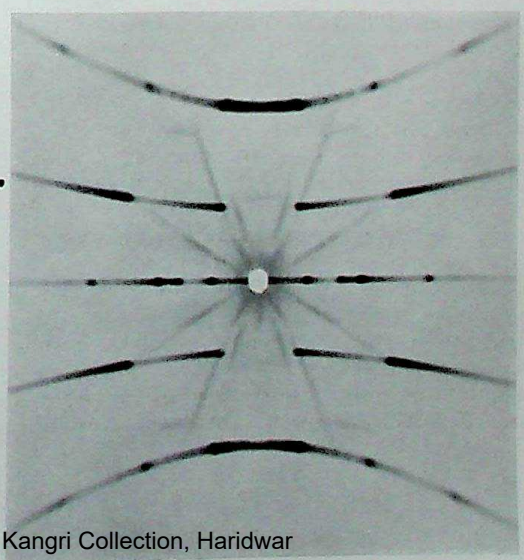

FIGURE 14

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The action of X-rays on living cells

J. A. CROWTHER

Modern science attacks specific problems from many different directions simultaneously. It is probably this method of concerted assault which, more than any other factor, has led to the remarkably swift progress of the last half-century. In the following pages, Professor Crowther shows how investigation of the action of X-rays on living cells may throw considerable light on the mechanism of heredity.

The discovery of X-rays was one of those germinal events in the history of science which, important in themselves, gain an increased significance as opening up fresh opportunities for further advances in many directions. The new tool was immediately recognized by the medical profession as a powerful aid to diagnosis, and the science of medical radiology has now reached a high pitch of perfection. Somewhat more tardily the engineer has come to adopt similar methods for testing the homogeneity and freedom from defect of the materials with which he works. In aeronautical engineering in particular, where considerations of weight make it necessary to trim down the margin of safety to its narrowest permissible limit, a radiographic test of important welds and castings is becoming a matter of routine. In an entirely different field the application of X-ray methods to problems of crystalline and molecular structure has led to notable advances on both the theoretical and the practical sides.

It is now becoming probable that X-ray investigations may prove at least as fertile when applied to some of the more obscure problems of biology. The territory lying between physics and physiology is certainly one of the richest of the as yet unexplored fields of science. Its successful exploitation requires close co-operation between the biologist and the physicist—a combination not easily secured. The progress that has been made so far, in this country, owes much to the far-sighted policy and generous assistance of the British Empire Cancer Campaign.

The action of X-radiation on living cells is invariably destructive. The therapeutic value of the radiation, which, in spite of some disappointments, is by no means small, is due to the fact that diseased and abnormal cells are more sensitive to radiation than the healthy tissues by which they are surrounded, and may be destroyed by doses of radiation which leave the healthy tissues unharmed, or at least not damaged beyond recovery. The extraordinary differences in radio-sensitivity of tissues of different kinds, and of cells of the same kind at different stages in their history, is a striking phenomenon, for which any theory must be prepared to account. Still more striking is the minuteness of the dose which, in certain cases, is sufficient to produce a marked biological effect. The mean lethal dose for the eggs of the blow-fly is only some 40 units, corresponding to a liberation of energy in the egg of rather less than one ten-thousandth of a calorie per gram.

A detailed study of the lethal action of continued irradiation on large populations of similar cells yielded even more surprising results. It is a matter of common observation that individuals in a population exhibit very different powers of resistance to adverse circumstances, such as exposure to extreme cold, to starvation, or to infection. A few weaklings may expire in the early stages of exposure, but the death-rate does not become serious until the onset has been so prolonged that it exceeds the average power of resistance of the individuals. The percentage of survivors then begins to fall rapidly. Even so, however, there will be certain particularly hardy individuals with powers of resistance well above the average, so that exposures much greater than the mean will be

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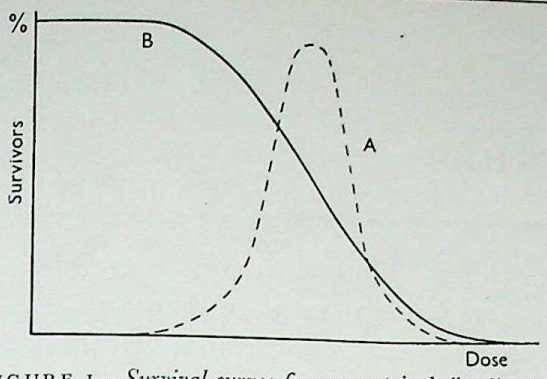

FIGURE 1 – *Survival curves for symmetrical distributions of vulnerability.*

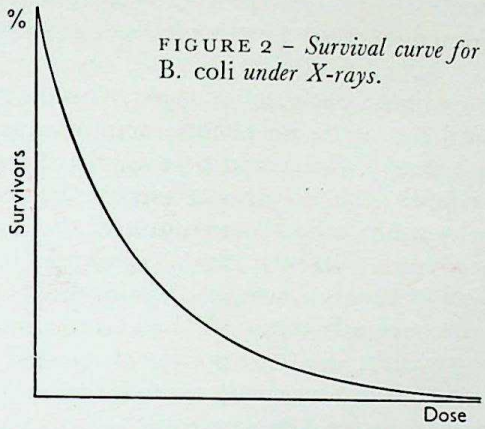

FIGURE 2 – *Survival curve for* B. coli *under X-rays.*

required to complete the process of extermination. Thus if we plot a graph showing the percentage of the original population surviving a given length of exposure, the resulting curve, known as a 'survival' curve, will be sigmoidal, as indicated by the full line in figure 1. The broken line indicates the distribution of susceptibility among the individuals in the population. The sigmoidal nature of the curve is simply an expression of the fact that some members of the population are more, some less, susceptible than the average.

Survival curves approximately of this type are not uncommon when the lethal agent is X-radiation. With X-rays, however, there are also many now well-authenticated cases where the survival curve takes quite a different course (figure 2). The number of deaths is actually at its highest at the first onset of the radiation, becoming progressively less as the exposure is increased. To explain this as a result of biological variations among the individuals we should have to assume not only that the sensitivity of the cells ranged from infinity to zero, but also that the largest group of the population is the one with the minimum of resistance. Such a distribution of sensitivity has never been found towards any other lethal agent. Moreover, close investigation reveals that this new type of survival curve is actually of the type known as an exponential. It indicates that whether exposure to the radiation has been slight or whether it has been prolonged, the death-rate remains absolutely constant. An individual bacillus, say, which has already been exposed to a considerable dose of radiation is, if it is still alive, no more likely to succumb to a further dose of radiation than one which has suffered no radiation at all. It is just as if a person, if deprived of further food for another day, were as likely to succumb to starvation immediately after a good dinner as after a three weeks' fast. For the resolution of this paradox we must look, not to the nature of the biological material, but to the nature of the lethal agent.

It is natural to imagine that in an object which is exposed to a beam of X-rays every individual molecule is subjected to the action of the radiation. It is, in fact, rather difficult to disabuse one's mind of this idea of uniform illumination. The idea is, however, very far from the truth. A beam of X-rays consists in fact of a swarm of *photons*, particles of energy of very minute size, and the absorption of X-radiation in matter consists in the stoppage of one or more of these particles by a single atom of the substance. The atom disposes of the energy so absorbed by ejecting a high-speed electron, which, in turn, ionizes a fraction of the molecules through which it passes, leaving a trail of charged molecules or ions in its wake, until its original energy is all dispersed. This process, which has been extensively studied, is very well illustrated by the photograph, due to C. T. R. WILSON, reproduced in figure 3. The photograph represents the passage of a beam of X-rays through air, from right to left of the

FIGURE 3 – *The passage of a beam of X-rays through air.*

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picture, and the individual ions have been rendered visible by depositing a drop of water on each—an invaluable technique originated by Wilson. It is obvious, from the picture, that the energy of the radiation has been concentrated on an extremely small number of molecules, the majority being completely unaffected by the rays. It is important to realize how highly discontinuous the action of the radiation can be. A particle of diameter as big as 0·2 μ, which would be distinctly visible in a good microscope, would stand a fifty-fifty chance of being untouched by a dose of 100 units; the passage of a beam of X-rays at an intensity of 1 unit per second for 500 years would still leave one-third of the individual molecules unscathed.

Now the chance that someone will be hit by a bullet fired at random is obviously proportional to the number of persons within range; and the number killed in a given time during a random attack will (assuming that every hit is fatal) be directly proportional to the number exposed to the attack. If the attack is continued the death-rate per thousand among the survivors remains constant, and the survival curve is exponential. Thus the exponential survival curves obtained when certain bacilli are attacked by X-rays, so mysterious when viewed from the biological point of view, are exactly what we should expect from the physical nature of the radiation, on the not unnatural hypothesis that the liberation of energy in some vital part of the structure of the organism is sufficient to cause death. The same hypothesis also affords a natural explanation of the observed independence of the lethal dose on the rate of irradiation, since the number of victims obviously depends only on the number of bullets fired, and not on the rate of firing.

The 'target' theory of the action of X-rays, as it is called, has not lacked influential critics. While the theoretical argument can hardly be controverted, it was suggested as recently as 1937 by SCOTT that the experimental evidence was insufficient to establish the exponential nature of the curves, and that they might be merely sigmoidal curves, with a very short initial flat portion. Brilliant experimental work by TIMOFEEF-RESOVSKY on the effect of X-radiation on gene-mutation, and of WYCKOFF on the lethal effect of the radiation on bacteria, has established the shape of the curves, for their particular material, beyond reasonable doubt. The 'target' theory is now accepted by most workers in the field. It is the only one which offers a rational explanation of the facts, and has the additional merit that it opens up a new avenue of approach to some important biological problems.

Let us assume that, in colonies for which the survival curve under radiation is of the exponential type, an individual will be killed if an ion is formed within some vital structure, a suggestion which I put forward in 1924 in connection with some early experiments of STRANGEWAYS in Cambridge on tissue cultures. Actually X-rays have a tendency to produce ions, not singly, but in very minute clusters, the average number of ions in a cluster being three. The volume of the sensitive region is obviously the volume in which the mean lethal dose has a fifty-fifty chance of producing one of these clusters of ions. Since the total number of clusters formed in unit volume by a given dose of radiation is known from physical measurements, the average volume which will contain one cluster can be calculated very easily. It is always much smaller than the volume of the whole cell. Thus X-rays act, not on the cell as a whole, but on certain specific structures within it. In many cases these structures turn out to be well below the resolving power of even the best microscope. It is obvious that X-rays open up an interesting line of investigation into the sub-microscopic structures of the living cell. Where the effect of the radiation is sufficiently drastic to produce the death of the organism, it may be difficult to identify the target with a known structure in the cell. Where, however, the immediate effect is the production of a 'mutation,' the structure can with some confidence be identified with a 'gene.' This line of investigation has been followed up energetically by Timofeef-Resovsky and others, with illuminating results. The same method has also been applied with some success to phages and viruses.

An interesting extension of the principle has recently been described in papers by LEA (of the Strangeways Laboratory) and HAINES, who have made an extensive study of the effect of radiation on the colon bacillus. It is well known that the density of ionization along the

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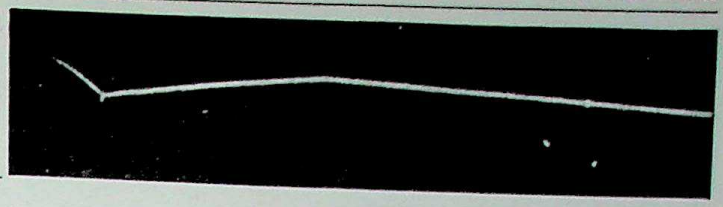

FIGURE 4 – *The track of an α-particle in air.*

Photograph by Professor C. T. R. Wilson.

Reproduced by courtesy of Edward Arnold & Company.

track of the photo-electrons ejected by X-radiation depends on the wave-length of the radiation. For short waves the density is small, for long waves the ion clusters are much closer together. The density becomes even greater if material particles such as the α-particles from radium are used as the ionizing agent. It can be seen from figure 4, which represents the track of an α-particle in air, that the ion clusters are so closely packed as to be indistinguishable in the photograph, and show as a continuous streak. The distance between the clusters formed by α-rays is in fact much smaller than the linear dimensions of the target volume of *B. coli*, as deduced from X-ray measurement, so that, whereas the X-ray leaves only one ion cluster in the structure, the α-particle might be expected to leave, perhaps, eighty. But since one cluster is sufficient to immobilize the cell, the remaining seventy-nine are completely wasted. Thus if both radiations are measured (as all ionizing radiations are now measured) by the total number of ions produced, α-rays should appear to be only one-eightieth as effective as short-wave X-rays. Direct comparison of the effects of different types of radiation on the colon bacillus demonstrated quite clearly that the lethal efficiency did in fact decrease as the ion density along the particle track increased, but by no means on the scale expected. The efficiency of the α-particles was in fact about one-eighth, not one-eightieth, of that of the short-wave X-ray.

To explain the discrepancy Lea has made the suggestion that the sensitive volume of the colon bacillus is not a single particle but is divided into a number of smaller particles, a hit on *any one of which* is sufficient to produce the ultimate death of the cell. Suppose, for example, that the sensitive volume is distributed among a thousand individual particles, the total volume remains the same, but the linear dimensions of each particle will be reduced to one-tenth. The chance of a hit remains the same as before, since it depends only on the total sensitive volume, but the number of ions left behind by an α-particle as a consequence of a hit is now only eight and not eighty times the number due to the X-ray, as required by the observations. The diameter of the particles was calculated to be 8·6 mμ.

Admirably as the suggestion meets the physical requirements of the problem, it is necessary to scrutinize it from the biological standpoint. Our target particle, of which there are about a thousand in a single bacillus, has a volume which would not be impossibly large for a single molecule, of molecular weight about 200,000. The particles are, presumably, of many different kinds, since it seems improbable that the destruction of one out of a thousand identical molecules could seriously inconvenience the cell. Moreover, since a single hit will ultimately cause the death of the cell, each particle is one which is vital for its proper functioning and one it is unable to synthesize again if it has once been destroyed. Since the organism cannot manufacture the particles it must presumably have inherited them, and must therefore be capable of duplicating them during the process of cell-division, so that each daughter-cell may have its full complement. This set of requirements appears to be quite fantastic until we realize, as Lea points out, that 'these are just the properties which current theory attributes to the *gene*.' If we regard a gene as a definite particle rather than a mere position in the chromosome, it would exhibit precisely that curious combination of properties which theory bids us postulate in our X-ray targets. The two best studied effects of X-rays are their ability to produce mutations and their power to kill. The experiments described give strong evidence that in each case the 'target' for the radiation is the same.

These experiments provide a straightforward and interesting illustration of the potency of X-radiation in the investigation of what may be called the fine-grained structure of matter: the region which lies between the atomic (about which much is known) and the actual

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microscopic. Thus though it is doubtful whether the existence even of chromosomes in *B. coli* has yet been demonstrated by the microscope, X-ray methods have enabled Lea and Haines to state with much probability that the bacillus contains some thousand genes of average diameter 8·6 mμ. It is beginning to be realized that in the inorganic world, as well as in the organic, 'fine-grain' particles may play a more important part than we had hitherto suspected. The colloidal state of matter owes its peculiar properties to particles within this range, and it is suspected that they play a part in many metallurgical phenomena.

Nothing has yet been said about the mechanism by which the production of an ion-cluster in the target particle brings about its lethal effect. DESSAUER many years ago suggested that this concentration of energy resulted in the formation of 'hot-spots' within the organism. Lea and his collaborators at one time suggested that the ions initiated a chemical reaction producing some poisonous substance in the neighbourhood of the target. They would possibly now regard it as being due to a rearrangement of the gene structure. It has always seemed to me to be possible that the action may be even simpler and more direct. Most of the structures in a cell-nucleus are known to be electrically charged, and, in particular, the phenomena of localized points of attachment in the chromosomes is strongly suggestive of the existence of localized electrical charges at various points of the structure. The production of a cluster of ions in the vicinity of these charges would lead to their neutralization, which, if we are right in suggesting that the attachments are electrical in origin, must cause a break-up of the system. Fragmentation of the chromosomes is, in fact, a common effect of X-radiation. Experiments which have been in progress in Reading for some time on inorganic colloidal solutions have demonstrated quite conclusively that both the mobility and the charge on the minute particles which make up these solutions can be profoundly and permanently altered by doses of X-radiation which are quite small, even when compared with those required to produce biological effects. Making full allowance for the natural tendency of a physicist to seek for explanations within the terms of his own science, the possibility that the biological effects of X-radiation result from a direct electrical action of the ion cluster which, as we have seen, constitutes a 'hit,' seems worth further investigation.

Recent work

THE PHYSICIST AIDS THE PHYSICIAN

Contributed by D. S. Evans *and* K. Mendelssohn, *Oxford*

It has been found possible to make considerable improvements in long-established medical practice when once the underlying physical principles were understood. One example of this work is the development of a vaporizer for the quantitative administration of ether vapour as an anaesthetic. By use of the familiar principle of the chemical thermostat the evaporation is carried out at a constant temperature. The vapour is thus kept at a constant pressure and can be mixed with controlled volumes of air or oxygen by the use of a simple mixer tap. The heat source for the vaporization is boiling water, which means that the operation of the machine is so simple that it is well adapted for use even under the difficult conditions of the field hospital or the casualty clearing station. The anaesthesia produced is always under perfect control, and may be conducted under medical supervision by a comparatively unskilled person. This type of machine is to be distributed to the British Army, and has in addition a very obvious peace-time value. An extension which is envisaged is the development of a simple apparatus for producing analgesia for use in the dressing of severe wounds and in childbirth.

Another example is the development of a simple semi-automatic device for the registration of blood-pressure and blood-flow in a limb during long operations. By means of a direct visual recording, a continuous indication is given to the anaesthetist and surgeon of the amount of blood flowing through the limb with each heart-beat, thus enabling an early diagnosis of shock to be made, and allowing remedial measures to be instituted before this dangerous condition is so far advanced as to be intractable.

Studies have also been made of the efficacy of radiant heat cradles for the treatment of shock, and it has been found possible so to modify their design that the rate of warming of the patient is greatly increased, while at the same time the risk of burning is decreased. The many possible applications of thermo-electric thermometers in medical practice are being explored, and a simple instrument has been devised for the detection of dangerous swelling of injured limbs encased in closed plasters.

The considerable progress which has been made in a short time is due to the application of physical methods by physicists to selected fields of medical practice, with the constant advice and assistance of medical specialists of great clinical experience.

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Phthalocyanines

C. J. T. CRONSHAW

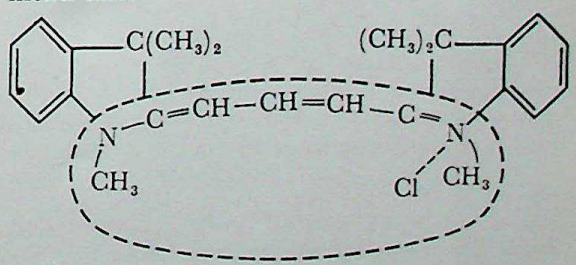
The search for new and better colouring matters is as old as history. Dr Cronshaw relates how examination of an accidentally discoloured batch of phthalimide led to the discovery of one of the most valuable of all known classes of pigment.

Fundamentally the organic chemist in his study of the relation of chemical constitution to physical properties is a designer and erector of buildings appropriate for particular purposes. He is therefore just as much concerned with problems of shape and size, of stresses and strains, of angles and dimensions, as is the architect proper; there are, too, both beauty and inspiration in such structures for those capable of appreciating the science. Moreover, the 'buildings' of organic chemistry are in principle, though more rarely in practice, erected from elementary units just as the builder lays brick by brick. This planned and deliberate synthesis of molecules is characteristic of organic chemistry, in distinction from inorganic chemistry.

The organic chemist in the practice of molecular architecture has given a particular name to those parts of the edifice which introduce the characteristic of colour; he calls them *chromophores*. A coloured substance is not necessarily a dyestuff—the latter results from the addition to the structure of certain other groupings in addition to the chromogenic part of the molecule—but alike for colour and for dyeing power the prime necessity is the chromophore.

The suggestion that the presence of chromophores within the molecule is responsible for colour in an organic chemical substance is an old one and was made by WITT in 1876. Whilst its validity remains true, the passage of years showed that it was perhaps only part of the story and required an additional conception. This we owe to that revered and dynamic personality, the late H. E. ARMSTRONG, who showed that many of the coloured substances then known had a structure similar to quinone, which itself is a pale yellow-coloured substance. That was in 1888. Quinone is a simple derivative of benzene and has two atoms of oxygen which create in the chemical structure a series of alternative stresses, and it is the existence of this conjugation of unsaturation within the molecule which gives rise to coloured substances. Recent work has added a further refinement in that whilst this chain of stresses preserves a sequence of 'stress' and 'no stress,' the particular incidence of any stress is not constant but oscillates and gives rise to what is called *resonance*. Actually the theory assumes an intermediate stage between the two changes as being the really effective state, much as a journey may start at A and finish at B and the rate of the journey be so incalculably swift that no traveller has ever seen the intermediate places which lie between the terminal points.

There are, of course, many rules in the technology of dyestuffs governing the relationship between constitution and physical properties, since so much else is required as well as the property of colour—for example fastness to light, an appetite for certain fibres, etc.; but whilst the requirements are infinitely varied this matter of the chromophores remains the heart and kernel of the whole affair. The nitro group NO_2 is a chromophore, and so is the well-known azo grouping —N=N—, which is, so to say, the single theme upon which the largest single family of dyestuffs is based. These examples are within the simplicity of the chromophores as originally conceived by Witt; other examples are more complicated arrangements like:



The portion within the area enclosed by dotted lines is the chromophore.

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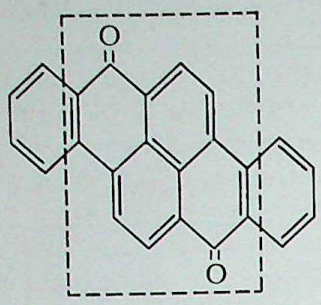
which is the beautiful pink dyestuff called Astrophloxine, and



The portion within the area enclosed by dotted lines is the chromophore.

which is the yellow compound called dibenzpyrenequinone.

Both these examples show a complexity beyond the original view of Witt, and fall within the modern conception of colour.

It is worth remarking in passing that just as the professional architect has his long row of cottages and his storied and more complicated edifices, so the chemist has simple compounds built up from long chains of single carbon atoms ('ribbon development'!), and also intricate compounds where carbon atoms are joined into a six-membered ring or even several such rings coalesced together.

The number of coloured organic chemical products is extremely great; the number of possible dyestuffs must run into a million or so; and the number of dyestuffs which by reason of special properties are commercially available is probably between two and three thousand. On the other hand, the number of chromophores is relatively much smaller. And whilst individual dyestuffs may lose their utility and become obsolete, invention and research more than balance the wastage, so that the total number available still grows. Indeed, an increasing demand for diversity and range of dyestuffs seems to go hand in hand with the progress of civilization. Even so, the discovery of a single new dyestuff usually ranks as an important event in both the science of organic chemistry and the technology of dyeing and printing. The discovery of a new chromophore is of course a much rarer occurrence, and always an important and exciting one, since it should open up a vast new continent for scientific exploration and technical endeavour. When, therefore, the constitution of the recently discovered phthalocyanines, published in the *Journal of the Chemical Society* in 1934, revealed the existence of a new chromophore the interest aroused was both natural and widespread.

This new chromophore fits with precision into the modern conception of colour and affords a splendid example of resonance. Although the existence of the phthalocyanines was not predicted, and was perhaps not even predictable, yet now the discovery has been made and the structure of the molecule ascertained, no one can fail to remark the inevitability of the compound. Its right to existence is almost declamatory! It is remarkable how readily at the appropriate temperature of reaction, and in the presence of a metal such as copper, the four integral components almost snap into position.

Phthalocyanines, themselves entirely products of the chemist's skill, have resemblances to two important substances which occur abundantly in nature. The first is chlorophyll, which is the green colouring matter in plants; and the second is haemin, which is the red colouring matter in blood. Both of these play an important part in the cycle of life in the two kingdoms, vegetable and animal, in which they are respectively so widespread. Whether this relationship implies any profound physiological properties for future members of the phthalocyanine series cannot be foreseen, and must await further scientific exploration. Both chlorophyll and haemin, however, are highly sensitive substances easily destroyed by light, heat, and even mild chemical reagents. Phthalocyanines, on the other hand, withstand the action of light and are amongst the 'fastest to light' substances known. They resist heat so well that the copper compound will sublime at about 600° C. without decomposition, a property which in itself is sufficiently remarkable to render the phthalocyanines unique in this respect among organic compounds. Phthalocyanines can be dissolved in concentrated sulphuric acid and reprecipitated without injury; indeed, this property is the basis of the method used on the commercial scale for their purification. They are insoluble in water and in nearly all organic solvents; and their resistance to the action of light, to organic chemical solvents, to heat, and to most acids, coupled

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with their great beauty and intensity of shade, put them into the front rank as pigments.

The phthalocyanines possess a further property which admirably adapts them for the special printing ink required for the so-called three-colour process used in colour printing. This in essence consists in making three printing plates, prepared by photographing the picture to be reproduced through selective colour filters in turn. Such plates are capable of printing as single images all the yellow, all the red, and all the blue portions of the picture. If prints are made from each of these plates (due care being paid to proper coincidence of the three images), so that each printing is superimposed—first the yellow, next the red, and finally the blue—a reproduction in full colour of the original picture results. All these processes, of course, call for great skill and appropriate materials, but it is essential that the yellow, the red, and the blue inks used shall be as nearly pure yellow, pure red, and pure blue as possible. If, for example, the yellow is an orange, that is yellow + red, or a greenish yellow, that is yellow + blue, or if the blue is a purple-blue, that is blue + red, then these secondary and adventitious shades are misplaced on the plates and when superimposed lead to dull reproduction.

Excellent trichromatic yellow and red pigments have existed for some time, but the full beauty of reproduction theoretically possible by use of the three-colour process could not be realized in practice by the use of ink based on existing blue pigments. The discovery of the phthalocyanines removed the remaining flaw in this method of colour reproduction. Monastral Blue (the trade name for the copper phthalocyanine compound), because of its purity of shade, is a perfect blue pigment for this purpose, and the comparative plates illustrated on page 83 show the extra range and clarity obtainable by the use of printing ink containing this pigment.

The phthalocyanines have, of course, all the range of utility for which pigments as a class can be employed. The only two blue pigments previously available with the characteristic of exceptional fastness to the action of light were Ultramarine and Prussian Blue, both well remembered by everybody as inhabitants of the box of paints in childhood days. Both have, however, serious shortcomings from which the copper phthalocyanine does not suffer: Prussian Blue is unfortunately damaged by alkalis and Ultramarine by acids.

The story of the discovery and the patient and skilful unravelling of the structure of the phthalocyanines is a splendid emblem of the happy marriage which has existed between the pure science of organic chemistry and the technology of the British dyestuffs industry, a union whereby a full and abiding partnership in observation and research can make invention a continuing reward.

The first member of the series was discovered by chance in 1928. It was observed that the manufacture of phthalimide in the Grangemouth works of Scottish Dyes resulted on occasion in a number of batches being slightly discoloured, and the phthalimide, therefore, was unsuitable for its proper purpose. Investigations on the spot by DUNWORTH and DRESCHER showed that the discoloration was caused by the presence of traces of a dark blue substance which was apparently formed during the reaction of molten phthalic anhydride with ammonia. The cause of this trouble having been ascertained, it was only necessary to adjust the conditions of manufacture so as to eliminate the undesirable impurity. There the matter might well have ended, but a detailed examination of the isolated impurity revealed too many marks of potential interest for the substance to be dismissed lightly from consideration. It was very stable and crystalline, and contained iron, which was apparently firmly entrenched as part of the molecule since it was not readily eliminated by the customary means. Moreover, and more important, it was a dark blue substance, and perhaps this was safeguard enough and to spare, in a dyestuffs works at any rate, against any tendency to allow such a substance to escape further and closer examination. The fact that it was coloured and insoluble in water instantly suggested its use as a pigment, but despite much experimentation and consideration nothing of utility resulted. A tribute is therefore merited to the people concerned, who despite the lack of promise had sufficient faith and interest in this novel substance to pursue the matter further. At the suggestion of the Research Committee of I.C.I. (Dyestuffs) Limited, DR LINSTEAD, of the

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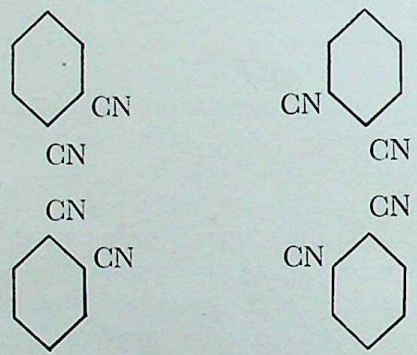
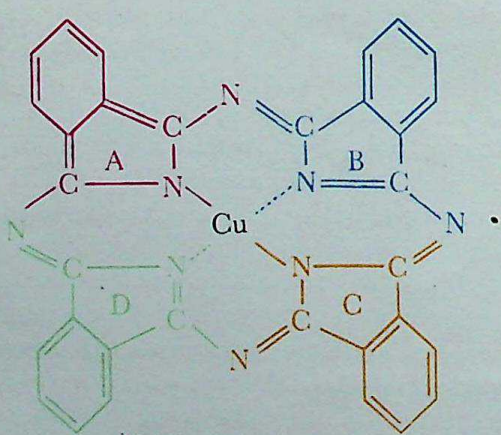
Imperial College of Science and Technology, London, took up the scientific study of the compound. To him also we owe the name which signifies both the origin and the deep blue colour.

The problem of the chemical constitution of the phthalocyanines was solved by Linstead and his co-workers, and was reported in the *Journal of the Chemical Society* in May 1934. From this date to 1939 the same journal contains a sequence of papers, including an X-ray confirmation of the structure by ROBERTSON, on these interesting compounds. The first member of the series, Monastral Blue B, was placed on the market in 1935. This peep behind the scenes illustrates the long, certainly active, and perhaps inevitable period of gestation required from conception to birth, even of a scientific discovery.

The chemical constitution can be considered as being built up out of four molecules, without loss, of phthalonitrile round a central nucleus which may either be two atoms of hydrogen or an atom of almost any metal. Thus:



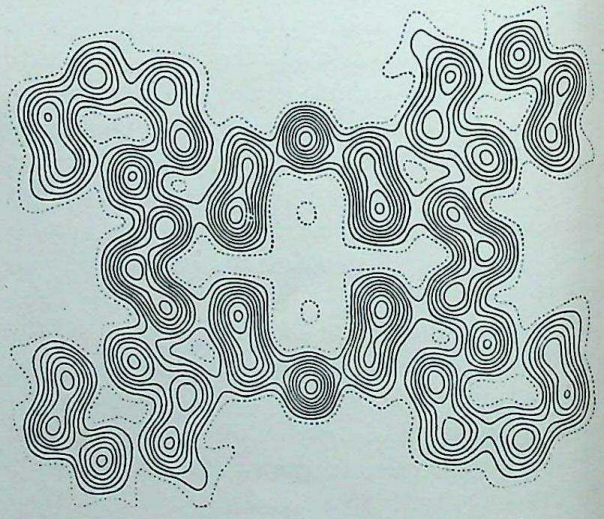
Four molecules phthalonitrile.



Phthalocyanine (copper).

In this representation the rings A, B, C, D differ in arrangement of 'stress' (indicated by the double bond) and 'no stress,' but the chemist believes that this represents, so to speak, only one snapshot in a cinematographic sequence, and that the difference is not permanent since all four rings successively take on all the structures in rapid alternation. This resonance in the structure accounts, according to modern conceptions, for the outstanding stability of these substances and possibly also for the colour. All the spokes uniting the copper hub to the external structure must be regarded as identical and equivalent, and it is a remarkable fact that two hydrogen atoms can replace the copper atom without loss of stability. This observation may stimulate modern work on co-ordinated hydrogen, an idea which was inconceivable a few years ago.

The scientific interest which the discovery of the compounds has aroused is by no means exhausted. For example, the metallic derivatives, particularly the one containing iron, have shown remarkable catalytic properties. Then, too, all members of the known series are either blue or green; but the dyestuffs chemist cannot readily accept such a restricted palette of colour as being the complete heritage resulting from the discovery of a new chromophore. Nor can the phthalocyanines be used, as yet, as dyestuffs for textile fibres. And so the work goes on, in the hope that perhaps only the first chapter of the full story is at present available.



An X-ray shadow picture of a phthalocyanine molecule.

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Comparative plates showing the extra range and clarity obtainable by the use of printing ink made with a phthalocyanine compound. The same set of blocks is used for both pictures; although in practice the photo-engraver would make some corrections in etching to compensate as far as possible for inaccuracies in the standard pigment.

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Vegetable drugs of Britain

and their exploitation in the war

R. MELVILLE

Great Britain has in the past imported from foreign countries materials that could have been grown at home. War has altered the picture, and, though deprivation may be irksome while it lasts, necessity has at least the merit of fostering our native resources. Dr Melville describes a case in point, and makes it clear that we can go far to grow our own needs of vegetable drugs.

The war has affected imports of all classes of merchandise. Imports of drugs, although considerable, form a relatively small part of our annual trade, but owing to their necessity for the national health bear an importance out of proportion to their size. Many drugs of tropical and subtropical origin must necessarily be imported, quite a number from temperate climates can be cultivated in these islands, and some are native. Although very few British plants are included with the more highly potent and well-established drugs of the *British Pharmacopoeia*, among them belladonna, henbane, digitalis, colchicum, and valerian, our ancestors made use of nearly every plant in the flora, often ascribing to them virtues that were non-existent and based upon some fancied resemblance to the organ they were supposed to remedy. Many of these have been discarded on account of the discovery of more potent remedies. Thus, comfrey root, long used in the treatment of wounds and ulcers, contains allantoin which stimulates cell-growth, but which is readily synthesized and, with other cell-proliferants, replaces the crude drug. Nevertheless a trade still exists in upwards of eighty native plants in amounts varying from a few hundredweights to many tons per annum.

Far the greater part of our supplies of these native drug-plants were imported from the Continent, often when abundant supplies could be grown at home for the trouble of harvesting. An outstanding example is dandelion root, of which about 250 tons per annum are used. As the reasons for this state of affairs were economic, not botanical, it should be possible as a war-time measure to organize the collection of some of the more important and extend the cultivation of others. Much has already been done on these lines. The area now under belladonna should provide for all, or the greater part, of domestic needs of leaf in a normal year, though root is likely to be scarce for some time. The cultivation of henbane, digitalis, and several other drugs has been extended, but more could be done with drugs requiring short-period cultivation such as caraway and valerian, as well as the aliens dill, lobelia, and psyllium. Uncertainty as to post-war conditions and difficulty in obtaining planting stock militate against much extension of cultivation of drugs requiring a long maturation period. Colchicum and male-fern do not lend themselves readily to cultivation on account of the small return obtainable for the long periods they take to mature, and both are normally collected in the wild. It does not seem likely that such plants can ever be grown economically except perhaps as a catch-crop among other long-term crops. Male-fern can be propagated by cutting off the crowns of large rhizomes for replanting when the rhizomes are dug. About ten years are then required to produce another rhizome 6 to 8 in. long. An opportunity exists for an enterprising landowner in the West of England to experiment with planting male-fern in mixed woodlands bearing not too dense a canopy, as the demand for this specific against tapeworms is likely to continue unabated.

The garnering of native British drug-plants may seem a simple business, but war-time collection is beset with difficulties at every stage.

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Transport for the collectors and the herbs gathered is hard to obtain; drying sheds requiring timber and other materials are a prime necessity and must be fitted up, while fuel is needed to provide heat to complete the drying in dull weather. Restrictions on all these commodities have hampered the work of the voluntary organizations assisting in the work of collection. An account of the steps taken to instruct collectors and other details of organization has been published elsewhere (*Pharm. J.*, 1941, **146**, 213).

Left: Meadow saffron in an open wood on the Cotswolds (Colchicum autumnale).
Right: Foxgloves on clay with flints, Surrey (Digitalis purpurea).

The Therapeutic Requirements Committee of the Medical Research Council has issued a list of twenty-six drugs recommended for increased production in the United Kingdom, of which eleven vascular and four non-vascular plants are native. Not all of the natives are abundant enough for collection. Belladonna was almost exterminated during the last war and its re-establishment was not encouraged on account of the danger of poisoning to domestic animals, so that few places remain where it can be collected. Henbane is rarely seen except as a casual; the wild forms of *Anthemis nobilis* and fennel are not those used in medicine. Valerian is scattered and difficult to collect in quantity; it is cultivated on a small scale and cultivation should be extended. On the other hand, colchicum is locally abundant on calcareous soils in the West of England, and considerable quantities of corms and seeds have been collected. Colchicum was formerly much more widespread and abundant, but the Ministry of Agriculture's campaign against it as a noxious weed has resulted in its extermination in many localities. The foxglove, *Digitalis purpurea*, is abundant and widespread on siliceous soils, including the clay with flints overlying chalk. The principal difficulty is to dry the leaves rapidly enough with the makeshift appliances voluntary workers have at hand, to preserve the bulk of the very unstable glycosides on which the medicinal activity depends. It is not possible to send fresh leaves by public carriers to distant drying centres, as drying must be started with as little delay as possible. Not nearly enough of this valuable drug was collected in 1941 to satisfy the demand. Digitalis seeds are used for the preparation of the glycoside digitalin.

There is much to be said in favour of a simple bitter for stimulating the appetite in dyspepsia and convalescence, and for this purpose dandelion (*Taraxacum*) might to a large extent replace gentian, supplies of which are difficult to obtain. Another common weed in great demand is the stinging-nettle, required for the preparation of chlorophyll. The pigment is extracted more readily from stinging-nettles than from other plants and is of a finer colour.

A number of other British plants are used medicinally, mainly by herbalists, in quantities of 1 to 10 tons per annum; but of more immediate interest is the prospect of preparing a satisfactory substitute for agar-agar from native seaweeds. Carrageen, *Chondrus crispus*, yields a mucilage widely used as an emulsifying agent. An agar-like substance can be prepared from it suitable for many industrial purposes, but not for bacteriological media. A wide range of algae has been tested but only the red seaweeds *Gelidium* and *Ahnfeldtia* have yielded agars of bacteriological quality. An ecological survey is now being made to determine whether adequate supplies for manufacturing are available round our coasts.

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Book Reviews

COSMOLOGY FOR EVERYMAN

The Birth and Death of the Sun, *by George Gamow. Pp. xiv + 238. Macmillan & Company Limited, London.* 1941. 12*s.* 6*d. net.*

It is not difficult to understand why the majority of laymen, when they are interested in science at all, find a peculiar attraction in cosmological problems. Such problems impinge at many points upon the general philosophy of life, and although the average man's urge to inquire into the ultimate nature of things may be only desultory, yet at one time or another 'everyone has feebly shaken with his hand the bough of truth.' This impulse, no less than the skill of the author, accounts for the popularity of *The Universe around Us* (SIR JAMES JEANS) and similar books. PROFESSOR GAMOW'S account of modern scientific views on the birth and death of the sun, on stellar evolution, and on subatomic energy would therefore be certain to find readers even if it were only mediocre. Far from being mediocre, however, it is among the best of its class, and if Jeans and Gamow rub shoulders on the bookshelf they will be good companions. But we are not convinced that the object illustrated in figure 7 of the book, and described by Professor Gamow as 'an ancient Persian electric battery' probably of the first century B.C., has any authentic claim to that identification.

THE BASES OF THERMODYNAMIC THEORY

The Nature of Thermodynamics, *by Professor P. W. Bridgman. Pp. xii + 229. Oxford University Press, London (Harvard University Press).* 1941. 20*s. net.*

PROFESSOR BRIDGMAN has already written on the logic of physics and on a particular application of thermodynamics, so that he is particularly well qualified to undertake an examination of the underlying bases of thermodynamic arguments. His outlook has evidently been influenced, consciously or unconsciously, by the deep analysis of physics which has been made in the past decade in connection with the newer mechanics. Nearly all discussions of this nature, whatever their subjects, end up by confirming the correctness of the procedure commonly used, and thus do little more than provide a secure foundation for a structure which they do not disturb. Professor Bridgman's essay differs from most in this respect, for he does offer a suggestion for the construction of a new wing to the edifice, and a direction in which experimenters might seek new phenomena. Throughout the discussion, the distinction between real experiments, conceivable experiments, and pencil-and-paper work is carefully made; the influence of language on our mode of thought is also a prominent theme.

In the first of the four chapters into which the book is divided, the author examines fairly exhaustively the generalized law of the conservation of energy. The questions of the localization of energy and how far a flux of energy is a flux of *anything* are discussed in some detail.

The second chapter deals with entropy and the second law of thermodynamics. Here the modern developments of experimental technique, which enable us to observe statistical fluctuations in such phenomena as Brownian movement and the small-shot effect, have made a re-examination imperative. It no longer seems so outrageous as it once did to imagine a mechanism which should sort out faster molecules from slower ones, and thus (by an inanimate material agency) create a temperature difference where previously there was none. It is possible, of course, that there is something in the nature of atoms and molecules which would prevent this; the signal (presumably of radiation) by which the atom heralds its approach might react on the particle in such a way as to prevent the mechanism from working.

In addition to these two chapters, which occupy about four-fifths of the book, there are a recapitulation and a short but intensely interesting chapter on 'miscellaneous considerations,' including a penetrating analysis of the principle of detailed balancing.

This short account of the book must give a very imperfect idea of the contents, but this is of little importance, for all physicists who are interested in the rationale of what they are doing should read the original.

J. H. AWBERY

SOME PROBLEMS OF DESERT ARCHITECTURE

The Physics of Blown Sand and Desert Dunes, *by R. A. Bagnold. Pp. xx + 265. Methuen & Company Limited, London.* 1941. 24*s. net.*

MR CASAUBON remarked with regret concerning his young cousin, that he had 'no bent towards exploration, or the enlargement of our geognosis.' Such a charge cannot be brought against LIEUT-COLONEL BAGNOLD, whose distinction as a traveller is well known, and who has, in this his latest book, made a notable addition to our knowledge of the physics of the earth's surface. And it is specially pleasant, in these days of physical experiments carried out on an engineering scale, to record one's appreciation of the work of an investigator who can observe closely such impressive natural phenomena as the growth and movement of gigantic desert dunes, and can seek—and find—an explanation of his observations in simple, ingenious and carefully controlled laboratory experiments.

The phenomena which the author records are indeed most impressive in their magnitude and regularity. To those of us whose knowledge of sand dunes is limited by the chaotic and disordered dunes of our own shores, overgrown with vegetation and trampled by men and animals, there is something awe-inspiring in the author's description of 'vast accumulations of sand weighing millions of tons' moving 'inexorably, in regular formation over the surface of a country, growing, retaining their shape, even breeding, in a manner which, by its grotesque imitation of life, is vaguely disturbing to an imaginative mind.'

The problem which the author faces is, in general terms, that of the transport of particles of solid by fluids—a problem which has attracted

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much, if unsystematic, attention in various branches of applied science: the author mentions, *inter alia*, the use of air-blast for the carriage of grain and of coal-dust, the drifting of snow, and the carriage of silt by rivers. In most instances the knowledge gained is empirical, and the author's work may be considered as that of a pioneer in a difficult and fascinating region.

The book is divided into three sections. The first section deals with laboratory investigations—in which the wind-tunnel plays a large part—of the mechanism of sand-movement. The author shows clearly that particles of the dimensions conventionally given to sand-grains are not, as is commonly supposed, lifted high in the air and carried over great distances, when sand-storms occur. The movement of the greater portion of the mass of sand in motion is confined to a very small height above ground level, and the sand advances by a process of *saltation*—a series of leaps or bounds, alternating with impacts on the ground surface. The second section deals with the formation of ripples and sand-ridges, and the third section with the growth and movement of dunes and with the description and analysis of two types of dune—the barchan dune and the seif dune. Despite the work of CARUS-WILSON and others, much remains to be learnt concerning singing sands, and all physicists will welcome the inclusion in the third section of a chapter on this intriguing subject.

The author is to be congratulated on an attack on a difficult problem which will serve as a model for future workers in this and allied fields. His book may be unreservedly commended to all who desire to enlarge their geognosis.

ALLAN FERGUSON

MODERN WORK ON GENETICS

New Paths in Genetics, *by J. B. S. Haldane. Pp.* 206. *George Allen and Unwin Limited, London.* 1941. 7*s.* 6*d. net.*

The book contains a series of lectures delivered by one of the leading exponents of genetics, at the University of Groningen, Holland, in March 1940. It is intended to show in its five chapters that genetics occupies a central position in the world of science and that it helps to bridge the gaps between bio-chemistry, embryology, and medicine. PROFESSOR HALDANE has shown some of the lines along which genetics has advanced and along which further progress can be expected. The reader will not fail to be impressed by learning how new methods, many of which are the contribution of Professor Haldane himself, have been, and are being, invented and introduced into genetical research. The book contains a great wealth of interesting and important information, presented often from an entirely new point of view, and one regrets that it is unlikely to be so widely read as it deserves to be, owing to the technical terminology, the intricate statistical analysis, and the discussions on the relationship between complex chemical processes, perusal of which would require great determination on the part of one not an expert in the various fields of science. An introductory chapter with a brief exposé of the fundamental principles of heredity would have been a great help to the reader who is not a geneticist.

The value of new methods in genetics is demonstrated in various ways. It is startling to learn that while the causal analysis of many human abnormalities is at present incomplete, purely statistical methods enable us to say a great deal about their mode of determination. Although the statement that 'in the next thousand years the frequency of recessive diseases will gradually increase in urbanized communities, due to increased in-breeding,' may at first appear dogmatic, it is, nevertheless, an inescapable conclusion from the application of the new statistical methods. It is pointed out that when predictions concern the individual there is always an element of uncertainty, but when genetics deals with millions, such as the constitution of human populations, 'probability becomes certainty and conjecture accurate prediction.'

The book contains occasional references to the implications of genetics in politics. The reader may find that the views expressed are not always impartial; but even when they are somewhat tinged, he will agree that Professor Haldane has made him aware of the danger which lies in the fact that a political system, such as that of present-day Germany, can claim a 'scientific basis' for its justification. Professor Haldane shows that the extreme form of the theory of racial superiority is erroneous and that evidence is still lacking which would prove that racial crossing is necessarily harmful.

It is hoped that the book will help towards a deeper understanding of many important and urgent problems of human genetics. For non-geneticists it may be pointed out that the title of the book should more properly read '*Some* New Paths in Genetics,' because Professor Haldane deals only with those lines in which he is personally interested.

P. G. K.

BIOLOGY BY CINEMA

Cine-biology, *by J. V. Durden, Mary Field, and F. Percy Smith. Pp.* 128, *with numerous illustrations. Penguin Books Limited, Harmondsworth.* 1941. 6*d.*

This little book—one of the popular 'Pelican' series—deserves, and will doubtless achieve, a wide success. Its text is unpretentious but good popular science, dealing with *Amoeba*, *Paramecium*, *Hydra*, and other invertebrates in a style likely to hold the interest of the general public. What will appeal to the scientific reader is the wealth of fascinating and beautiful photographs, mostly taken from the well-known *Secrets of Life* films of Gaumont-British Instructional Limited. The patience and skill necessary to obtain such photographs cannot easily be estimated except by the expert, but some idea of the difficulty involved may be gathered from the statement in the book that it took months to discover *Paramecia* in conjugation, all efforts—including those of professional biologists—to bring conjugation about deliberately having completely failed. Other subjects most admirably illustrated are *Stentor*, *Vorticella*, *Obelia*, *Aurelia*, and *Peripatus*, as well as some arachnids, crustaceans and insects. Perhaps the most effective of the photographs are those of *Daphnia*, but each of the illustrations is worth the modest sixpence for which the book is obtainable.

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Born in 1890, he was educated at University College, London, where he became Andrews Scholar, Trouton Research Scholar, and Carey Foster Research Prizeman. He went to the Rothamsted Experimental Station in 1913 to explore the possibilities of applying modern physics to soil problems, and after military service during the first world war returned there in 1919, becoming Assistant Director in 1923. He is one of the editors of the *Journal of Agricultural Science*. He has travelled extensively in the United States, South Africa, India, and Europe.

The Rothamsted Experimental Station at Harpenden, Hertfordshire, was founded in 1843 by J. B. Lawes (1816–1900). With J. H. Gilbert (1815–1901), Lawes initiated in Great Britain the scientific investigation of artificial fertilizers and erected the first factory for their manufacture. The scope of the agricultural experiments at Rothamsted steadily widened; laboratories were built, field plots laid out, and careful statistical records kept. By the end of the nineteenth century, this quiet English manor had become one of the principal foci of agricultural research not only in Britain but throughout the world, and in 1909 its status was officially recognized by the Government, which granted it financial support. The present Director is Sir John Russell, D.Sc., F.R.S.

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Was born in London in 1887 and was educated at St. Dunstan's College, the Universities of London, Manchester, and Heidelberg, and the Cavendish Laboratory at Cambridge. Since 1928 he has been Quain Professor of Physics in the University of London. He served as an artillery officer in France in the war of 1914–18, and afterwards was for some years professor at the Artillery College (later the Military College of Science). His interests are wide and varied, ranging from the history of science to art, poetry, and music. He has established a flourishing school of physics at University College, where his laboratory was completely destroyed by bombs in September 1940. Since the beginning of the present war he has been in Government service as Scientific Adviser in the Ministry of Supply.

F. SHERWOOD TAYLOR,
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Was born in 1897 and educated at Sherborne School and Lincoln College, Oxford. For some years from 1921 he was a schoolmaster, but soon became known to a wide circle of the general public as a successful expositor of science. Though he acknowledges that his purpose in life is 'to know a little about as many subjects as possible,' he is deeply versed in the history of science, particularly Greek alchemy, and was editor of *Ambix* from 1937 to 1939. Since 1940 he has been Acting Curator of the Museum of the History of Science at Oxford.

W. T. ASTBURY,
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Is a leading expert on textile physics, specializing particularly in the structure of proteins and of natural and artificial fibres. Born at Longton, Stoke-on-Trent, in 1898, he was educated at Longton High School and Jesus College, Cambridge, afterwards becoming Assistant to Sir William Bragg at University College, London, and the Royal Institution. In 1928 he was appointed Lecturer in Textile Physics in the University of Leeds, where his brilliant researches earned him a Medal from the University of Lille, the Gold Medal of the Company of Dyers, and the Warner Memorial Medal of the Textile Institute. He finds his principal relaxation in music.

J. A. CROWTHER,
M.A., Sc.D., F.Inst.P.

Is a Yorkshireman, having been born at Sheffield in 1883. He was educated at the Royal Grammar School, Sheffield, and St. John's College, Cambridge, and for a dozen years from 1912 carried out research in the Cavendish Laboratory. From 1921 to 1924 he was Lecturer in Physics Applied to Medical Radiology in the University of Cambridge, a post which he relinquished in the latter year on his appointment to the Chair of Physics in the University of Reading. His contributions to the original literature of his subject have been numerous and important, but—in normal times—he likes occasional moments of leisure for tennis and bridge.

C. J. T. CRONSHAW,
B.Sc., F.I.C., F.R.S.E., M.I.Chem.E., Hon. D.Sc. (Leeds)

Was educated at Bury Grammar School and Manchester University, afterwards entering the chemical industry. Here his chemical instinct and organizing ability found full scope, and he was elected Vice-President of the Society of Chemical Industry in 1935. Four years later, he became President of the Society of Dyers and Colourists and a Member of the Council of his old university. He has contributed numerous articles on dyestuffs and related topics to technical and scientific journals and possesses an unrivalled knowledge of the dyestuff, colouring matter, and pigment industry. He is Chairman of the Dyestuffs Group of Imperial Chemical Industries.

RONALD MELVILLE,
Ph.D., F.L.S.

Is a native of Bristol, but soon removed to Cardiff, where he studied pharmacy at the Welsh College of Pharmacy, gaining the M.P.S. and Ph.C. diplomas. Breaking away later from pharmacy he joined the staff of the Imperial College of Science in 1930 and engaged in research on physiology of the tomato. He took up his present post on the Museum staff of the Royal Botanic Gardens, Kew, in 1934, and now deals with questions of economic botany, especially those concerning medicinal plants and the taxonomy and uses of hardy trees and shrubs.

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ENDEAVOUR

A quarterly review designed to record the progress of the sciences in the service of mankind

VOLUME I JULY 1942 NUMBER 3

The scientist's responsibility

In our present issue, letters from distinguished correspondents raise the question of the place of science in society. The question is one of the first importance, for science profoundly and intimately affects every detail of civilization. Its future influence will inevitably be still greater. But in any discussion of the interrelation of science and society, it is essential to have a precise idea of the relevant connotation of the term 'science.' Among the general public 'science' is frequently used in a sense at once too wide in certain respects, and too narrow in others. Sharper definition attaches to the term if we equate it to 'the sciences,' and it is with this meaning that we employ it here.

The fundamental problem confronting science in the ethical sphere is that of making itself known to mankind as a whole. What fraction of the population of any civilized country—even our own—can be credited with a proper conception of science, its aims, its methods, its results? On the most generous estimate it must be very small. Ignorance of science is by no means confined to the humbler ranks of society. It pervades every walk of life, from the lowest to the highest. It is particularly reflected in the popular press. Each day the newspapers contain elementary errors, misleading references, or out-of-date statements concerning scientific progress and discovery. It is not all their fault. There is nowhere among men of science a general disposition—or indeed ability—to see that the current thought and practice of laboratory and lecture hall are made available to the public through the press, the cinematograph, and other media. There is frequently, it must be confessed, a tendency to avoid contact with the newspaper reporter instead of teaching him to be an accurate and intelligent translator. It is therefore not surprising that the scientific attitude of mind is misunderstood, and even mistrusted, by the public. How slender is the footing which science has won in the popular mind can be inferred from the smouldering fires of astrological superstition, now being fanned into flame by the winds of war. How little even the educated Englishman knows of the achievements of British scientists, either past or contemporary, is shown in his proneness to assume that chemical genius and organization are German monopolies.

The remedy lies in the hands of scientists themselves; and in no country have they a more insistent duty than in Great Britain, for there is no other country with heavier political responsibility overseas, and none whose national characteristic is more typically reticence and understatement. Science, indeed, must become articulate. Even though publicity may be repellent to scientists, they must, as a body, vie with the politicians, for science holds the keys of the future.

There is here an opportunity for concerted action on the part of the various scientific bodies and associations in the British Isles, and indeed in the British Commonwealth of Nations. Certain steps could be taken immediately. The Government should be pressed to encourage a wider teaching of science in the primary schools, so that all children, and not merely those attending secondary schools, might get at least some basic notions of what science is about. It is still more vital to devise methods of reaching the adolescent, whose scientific education (except in the case of those who adopt a scientific profession) stops abruptly with the end of school life. If it could be carried on by the greater use of broadcasting, by a much larger number of public lectures, by science features in the daily and periodical press, by the publication of more popular books on science, and in general by abandonment of the scientist's attitude of aloof silence, we might confidently expect a nation ready to understand and able to use the illimitable resources of mind and matter. It is

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idle to expect to capture the latter mind, grown set in its habits of thought, its opinions and its prejudices. On the other hand, to teach the rudiments of science up to the age of 16 and then cease is to waste the harvest of sown seed. The formative process must be continued through the receptive years of early manhood and womanhood, and only scientists can ensure its continuation.

Lastly, if science is to become articulate, it must be taught to walk more closely in step with letters. It is no disparagement to admit that men of science seldom show themselves masters of prose expression. There are of course notable exceptions—the names of DAVY, FARADAY, T. H. HUXLEY, WILLIAM BRAGG spring at once to the mind—and indeed the chief cause of the taciturnity of science is probably not lack of literary ability but the exacting and engrossing nature of scientific research. The urge to pursue original investigation tends to overshadow the urgency of the public relations of science, so that a task which ought properly to be undertaken by leaders is too commonly relegated to less competent hands. This condition of affairs must be repaired. Science must, in short, learn how to express itself—it must not only accept its responsibility to the public, but acquire the knowledge of how to discharge it.

Correspondence

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., Imperial Chemical Industries, Nobel House, Buckingham Gate, London, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

THE FUTURE OF RESEARCH

From J. B. S. Haldane, M.A., F.R.S.

The leading article in the April number of ENDEAVOUR [p. 49] raises a number of important issues. First let me controvert one point. You state that 'In both camps the main and practically sole activity of scientists is directed towards the solution of immediate problems.' This is unfortunately untrue of biologists. Our leaders both in war and industry do not fully realize that the abnormal conditions under which men and women are fighting and working raise enough physiological problems to justify a very large volume of research, some of which would be fruitful at once.

With regard to post-war policy, the writer of the article seems to see no possibilities but either 'the pursuit of knowledge for the sake of knowledge' or its 'application to the amelioration of human existence.' This is a reflexion of the sharp distinction between pure and applied science, between the university and the factory scientist, which characterizes our society. This distinction is not in the nature of things. The founders of the Royal Society were men of intense curiosity, yet they valued 'no knowledge but as it hath a tendency to use.' Large and progressive modern firms allow many of their scientific workers ample opportunities for 'pure' research, and find it pays. In the Soviet Union before the war this tendency had gone very far. Industrial scientists generally did some teaching. Academic research institutions were assigned practical problems, which did not, however, occupy their full time. There was frequent interchange of personnel between laboratories of the different types.

I believe that the best conditions for research, and the happiest for scientists, arise when theory and practice are not separated, but the same man or woman spends part of his or her time with the nose applied to the grindstone of applied science or teaching, and part in the ivory tower of 'pure' research. If the majority of scientific workers would agree that this was a desirable aim, steps might be taken to see that it was realized to some extent at least during post-war reconstruction.

From J. R. Baker, M.A., D.Phil., D.Sc.

British scientists have gladly offered their services to the nation for the period of the war, for use in any way the Government thinks fit. That is right and proper, because modern war is a relatively short-term affair. It is curious to reflect that if this war were likely to last for fifty or a hundred years, the best policy would probably be to leave scientists entirely free to follow their own inclinations. The great technological advances, from the applications of electro-magnetic induction downwards, have nearly always sprung from scientific research carried out by men of genius or talent who wanted to know more about the universe and did not dream of practical results when they were carrying out their work.

Great discoveries are unlikely to be made if after the war we organize science in Britain on totalitarian lines, with the scientific research worker—the only man who counts in discovery—as the lowest term in a hierarchy of planning committees and scientific dictators. As WALTER LIPPMANN has urged in his book *The Good Society*, there is only one thing that can be centrally planned with success, and that one thing is war. Hence the success of totalitarian methods in war should not make us think of totalitarianism as a progressive force in any other sphere.

A growing body of British scientists is

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now at last becoming alive to the danger inherent in the demand that science should be centrally planned. One must hope that in the period of reconstruction after the war Britain will maintain her proud position as the champion of liberty not only in the ordinary political sphere, but also over the whole range of human activity, including science and all other branches of culture.

From J. D. Bernal, M.A., F.R.S.

The experience of the war has emphasized, as your April Editorial pointed out, the importance of the organization of scientific effort. There is no reason, however, for the fear that as a result of the experience of the war the development of free science will be curtailed or stunted. Effective organization of science implies neither an exclusive concern with problems of immediate application nor the subjecting of scientists to the discipline of a rigid and unimaginative bureaucracy. Those who have been working for an improvement of the present chaotic system of science in the direction of using it more effectively for human welfare realize fully that any such developments would immediately frustrate their ends. If applied science was exclusively followed, the basic principles on which any new development, however practical, must depend would never be elucidated. It is quite possible for us to see now that, from mathematics to psychology, there is no branch of science that is not needed in one way or another for some application, either now or in the near future.

All branches, therefore, must be cultivated—as they are cultivated, in fact, in the Soviet Union. This does not preclude their cultivation for their own sake by people who enjoy studying them, and even their extensive development on a scale many times that attempted at present even in the countries of the freest science.

Similarly, the planners of science recognize old-fashioned humanistic bureaucracy as an enemy of science. Until a new, scientifically minded bureaucracy can be built up, the organization of science would need to be in the hands of scientists themselves—and not merely of those of senior scientists, but with democratic control that is fully representative of junior scientists and technicians. Only such democratic organization can secure the real freedom of science, which includes, not only the freedom of discovery, but the freedom to see those discoveries applied. The present freedom of science has reduced the status of the scientist to that of an ineffective dreamer or practical slave to interests far removed from the ideals of science. A free society cannot do without organization—nor can free science.

CHEMISTS AND CHEMISTRY

From E. F. Armstrong, D.Sc., LL.D., F.I.C., F.R.S.

The last war found us largely unprepared as chemists and chemical industry. The lessons were taken seriously to heart, and in 1939, on the outbreak of war, chemists were probably in a better state to meet the emergency than any other section of the community. Two reasons for this were the large and increasing number of highly trained and fully qualified chemists available, thanks to the universities and colleges; and the close co-operation during the last twenty years of the industrial leaders and firms in chemical industry. After all, chemists are the real basic raw material of our industry, and we cannot have too many of them, provided they are of the best. Others should be discouraged at an early stage. The chemist must remember that he gets his first post largely on his teacher's recommendation, but that his future depends on his own ability as a man and a chemist: he has to apply and make useful what he knows.

This war has shown that we are on right lines. There is a need for chemists and chemical engineers if we are to solve the economic problems of the future, and some of us are trying hard to teach the administration and the politicians the truth of the above. But what have we to learn? Surely to be strong in our own house. Every help must be given by firms to the universities so that they have up-to-date and well-equipped laboratories. Some firms already do this generously, but a laboratory is out of date in twenty years, so far more help is needed. Equipment, not endowment, is required. Good workshops and good teachers mean able students and first-class research: a steady flow to a progressive industry.

There are wide fields for our chemical industry to capture. But success is exacting—none but the best will serve to gain it.

JOHN FERGUSON

From John Read, M.A., Sc.D., F.R.S.

I should be obliged if you would record the following bibliographical references originally appended to my article in your January issue (pp. 36 and 37):

[1] J. FERGUSON, *Bibliotheca Chemica*, 2 vols., Glasgow, 1906. [2] *Op. cit.*, 1, viii. [3] J. J. MANGET, *Bibliotheca Chemica Curiosa*, 2 vols., Geneva, 1702. [4] T. S. PATTERSON, *Annals of Science*, 1937, 2, 297. [5] T. S. PATTERSON, *Glasgow University Magazine*, 6th December, 1916. [6] F. O. BOWER, *idem*. Without these references, justice is not done to my indebtedness to the quoted writings of Professor T. S. Patterson and Professor F. O. Bower relating to John Ferguson. So far as Professor Patterson is concerned, this indebtedness extends also to the final paragraph of the article. In view of conflicting evidence bearing upon the date of Ferguson's birth, I may add that an official extract from the register of births for the parish of Alloa, kindly sent to me by Mr J. W. Napier, records that 'John, lawful son of Mr William Ferguson and Margaret Kidd,' was born there on 24th January, 1838.

[NOTE: *We regret that very heavy pressure on space in our inaugural issue necessitated omission of this list of references, and are happy now to publish it, together with* PROFESSOR READ'S *interesting addendum.* EDITOR.]

APPLICATIONS OF PHOTOGRAPHY

From George A. Jones

The Association of Scientific Workers is organizing an exhibition which will be held in November at the premises of the Royal Photographic Society. The exhibition is to illustrate the applications of photography to science, medicine, and industry with a view to making such information more generally available and better known to the public. The Photographic Committee of the Association, anxious to obtain examples of such work from as wide a variety of sources as possible, appeals to those who may be able to provide exhibits to write for further details to the Hon. Secretary, Photographic Exhibition Committee, Association of Scientific Workers, 73 High Holborn, London, W.C.1.

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The red and blue colouring matters of plants

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SIR ROBERT ROBINSON

Aesthetic appreciation of colour is possibly as great among chemists as among artists. But whereas the artist experiences an urge to employ colours, the impulse of the chemist is to probe their chemical composition. Particularly seductive are the red and blue colouring matters of plants, and in the following pages Sir Robert Robinson tells the fascinating story of the way in which he and other workers have mapped the molecular architecture of these complex substances.

The chief groups of vegetable pigments are (*a*) green chlorophyll and its analogues; (*b*) yellow and orange carotenoids, generally insoluble in water and soluble in organic solvents; (*c*) miscellaneous pigments such as those related to anthracene and the colouring matters of fungi; (*d*) the large classes of water-soluble pigments comprising especially the yellow anthoxanthins and the orange, red, magenta, violet, and blue anthocyanins. Our present accurate knowledge of the chemistry of the last group has been gathered since 1913, in which year WILLSTÄTTER and EVEREST published an account of their pioneering researches on cornflower blue. That is not to say that nothing was known previously; indeed, the reactions of the anthocyanins with acids and alkalis were observed by ROBERT BOYLE and NEHEMIAH GREW, and later by many others.

BERZELIUS (1837), MOROT (1850), HEISE (1889), GLAN (1892), and GRIFFITHS (1903) attempted with varying success to isolate the pure pigments, and the results were by no means negligible although the objective was never reached. From the work of Heise and of Glan it appeared that the anthocyanins might be nitrogen-free glucosides. This view was emphasized by the botanist MOLISCH (1905), who showed that anthocyanins sometimes occur in flowers in the crystalline condition and could often be crystallized outside the plant. A well-known experiment of Molisch can be repeated by anyone. Take a few petals of the scarlet pelargonium; roll them on a microscope slide with a glass rod so as to break up the structures. Then add a few drops of acetic acid (80 per cent.), cover with another slide, and set aside for slow evaporation. The acetic acid dissolves out the orange-red pigment and, as the solution concentrates, crystals appear, especially round the edges.

GRAFE (1906–11) carried out a similar process on a larger scale, but unfortunately his examination of this material did not result in any notable advance.

The isolation, characterization, and analysis of many pure anthocyanins were effected by Richard Willstätter and his collaborators (1913–17). The technique varied from case to case, but the standard procedure depended on the recognition that the pigments exist as salts in acid solution. The plant material, usually dried petals of flowers, was extracted with methanolic or ethanolic hydrogen chloride or with acetic acid. The crude pigment salt was precipitated from the solution by addition of a large volume of ether, and this or a similar process might be repeated. The anthocyanin chlorides were then crystallized from aqueous or alcoholic hydrochloric acid. Occasionally a picrate or other derivative was isolated as an intermediate stage in the purification.

In this way the blue or deep bordeaux-coloured cornflowers, the rose, and red dahlias afforded one and the same *cyanin chloride*, which is very sparingly soluble in aqueous hydrochloric acid (0·5 per cent.) and crystallizes in rhombic leaflets or microscopic needles, red by transmitted light and exhibiting a fine bronze lustre. The composition of the crystals is $2C_{27}H_{31}O_{16}Cl$, $5H_2O$, and $C_{27}H_{31}O_{16}Cl$ after drying at 105° C. in a high vacuum. Similarly the scarlet pelargonium afforded a beautifully crystalline (slender, orange-red needles) anthocyanin, $C_{27}H_{31}O_{15}Cl$, termed *pelargonin chloride*.

Complex as the molecules of these colouring matters undoubtedly are, the determination of their molecular structure was made without difficulty except for some details which were finally cleared up by the later syntheses. Boiling 10 per cent. hydrochloric acid brings about a

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decomposition by hydrolysis into new coloured salts called *anthocyanidins* and two molecules of glucose:

$$\underset{\textit{Cyanin chloride}}{C_{27}H_{31}O_{16}Cl} + 2H_2O = \underset{\textit{Cyanidin chloride}}{C_{15}H_{11}O_6Cl} + 2\underset{\textit{Glucose}}{C_6H_{12}O_6}$$

$$\underset{\textit{Pelargonin chloride}}{C_{27}H_{31}O_{15}Cl} + 2H_2O = \underset{\textit{Pelargonidin chloride}}{C_{15}H_{11}O_5Cl} + 2\underset{\textit{Glucose}}{C_6H_{12}O_6}$$

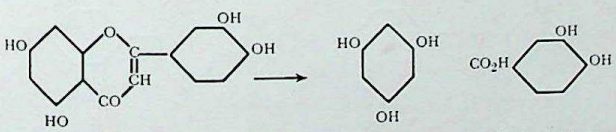
Thus these anthocyanins are diglucosides of the anthocyanidins and the process of decomposition is one with which chemists have long been familiar in the large classes of naturally occurring and synthetic glucosides:

$$C_6H_{11}O_5 - O - R + H_2O \rightarrow C_6H_{12}O_6 + HO{\cdot}R$$

The problem has now been greatly simplified; it is resolved into the recognition of the constitution of the anthocyanidins and the mode of attachment of the glucose molecules to them.

Now cyanidin chloride can easily be made to lose HCl, for example by treatment with aqueous sodium acetate (a weakly alkaline solution), when it yields a deep violet *colour base*, $C_{15}H_{10}O_6$. It could not be overlooked that this is the composition of the anthoxanthin *luteolin*, a yellow mordant dyestuff derived from *Reseda luteola*. The dried plant is called weld and is thought to be the oldest European dyestuff, having been used north of the Alps in the time of JULIUS CAESAR.

Luteolin, which is a typical anthoxanthin (*see above*), forms salts with strong acids, but these are much less stable and far less deeply coloured than cyanidin chloride. Its constitution (I) is known as the result of the labours of A. G. PERKIN and ST. VON KOSTANECKI and the substance has been synthesized by more than one method. A typical decomposition is illustrated and may be brought about by fusion with potassium hydroxide:

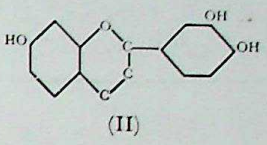


(I) *Phloroglucinol* *Protocatechuic acid*

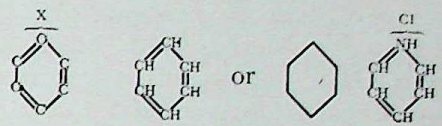
The substance of which luteolin is the tetrahydroxy-derivative is called *flavone* and a large number of variously substituted flavones had already been isolated from plant material.

In order to see whether there is really any relationship between cyanidin and luteolin, Willstätter and Everest fused the former also with potassium hydroxide and were able to isolate phloroglucinol and protocatechuic acid. It then seemed highly probable that cyanidin chloride contained the group (II).

Another series of researches, tending to confirm the deduction, concerned the constitution of the best-known group of relatively stable oxonium salts, so called by analogy with ammonium salts. Through the researches of COLLIE, BAEYER, WERNER, DECKER and FELLENBERG, and W. H. PERKIN and ROBINSON, it was already known that these invariably contain a structure known as pyrylium (III), which may be compared with benzene (IV) and pyridine hydrochloride (V):

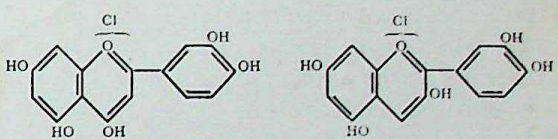


(II)



(III) (IV) (V)

Thus, in harmony with the pyrylium theory, luteolin hydrochloride would be (VI), and since the products of decomposition forbid us from suggesting modification of the benzene rings, the only possible cyanidin structure closely related to luteolin is (VII):



(VI) (VII)

[The bracket in these formulae indicates the electrovalency of salts as in $\overset{+}{Na}\}\overset{-}{Cl}$ or $\overset{+}{NH_4}\}\overset{-}{Cl}$ where charged ions are bound by electrostatic attraction. Such valency differs from the type represented by lines and exemplified by that in the hydrogen molecule, $H \times H$, which is non-polar (co-valency), the binding force depending on sharing of electrons between two atoms.]

The formula (VII) indicates that cyanidin chloride might be related also to the most widely distributed of all anthoxanthins, namely quercetin (VIII), and a rigid proof of the fundamental structure of the anthocyanidin was obtained when it was found that it could actually be produced by reduction of quercetin in acid solution. The reagent was magnesium in methanolic hydrochloric acid solution, and the fact that the yield was poor does not invalidate the experiment. The changes in the centre nucleus are shown in

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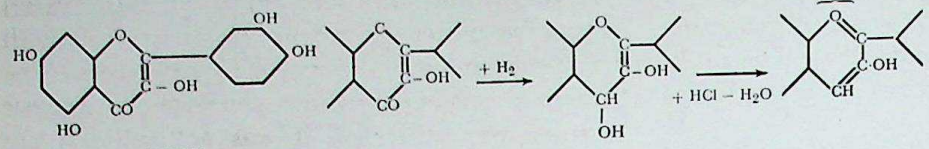
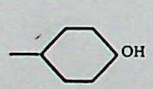
part formulae and they accord with analogies in other series:



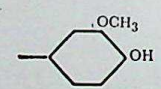
(VIII)

That (VII) correctly represents cyanidin chloride was later proved by several unambiguous syntheses, and moreover all the known anthocyanidins have been synthesized, as well as some hundreds of similar pyrylium salts. The only differences between them lie in the number, nature, and positions of the groups attached to the triple ring system.

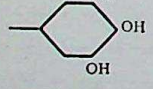
Later Willstätter and his co-workers isolated other anthocyanins. Delphinin chloride from delphinium flowers splits up into *delphinidin chloride*, $C_{15}H_{11}O_7Cl$, two molecules of glucose, and two molecules of *p*-hydroxybenzoic acid. The true analogue of cyanin and pelargonin based on delphinidin is *delphin chloride*, $C_{27}H_{31}O_{17}Cl$, and this was later isolated by SCOTT-MONCRIEFF and ROBINSON from flowers of *Salvia patens*. Anthocyanidins, which are methyl ethers of cyanidin and delphinidin, were also obtained by hydrolysis of various anthocyanins. Except in one case the variations are all in the right-hand nucleus and therefore this alone need be represented. As already stated, all have been synthetically prepared.



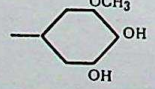
Pelargonidin chloride



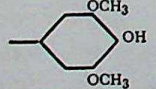
Peonidin chloride



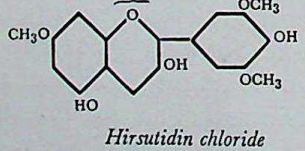
Delphinidin chloride



Petunidin chloride



Malvidin chloride

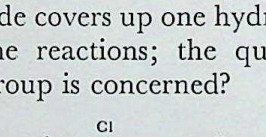


Hirsutidin chloride

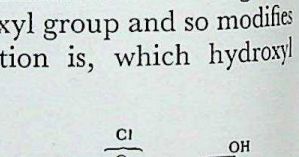
The most widely distributed are pelargonidin, cyanidin, delphinidin, and malvidin; hirsutidin occurs only in certain primulae.

The red poppy (*Papaver rhoeas*) is coloured by mecocyanin, an isomeride of cyanin chloride and also a diglucoside of cyanidin. Many monoglucosides are known, a few monogalactosides and many rhamnoglucosides and pentoseglucosides. A very common occurrence is acylation of a number of hydroxyl groups as in delphinin chloride. *Callistephin* from the aster (Willstätter) or the red carnation (Robinson) is pelargonidin monoglucoside. *Chrysanthemin* from the deep red chrysanthemum is cyanidin monoglucoside; *oenin* from the skins of purple-black grapes is malvidin monoglucoside; the monoglucoside of peonidin occurs in the skins of the larger cranberries from Newfoundland. Cyanidin monogalactoside colours the smaller European cranberries; it is called *idaein;* the red snapdragon (*Antirrhinum majus*) contains *antirrhinin*, which is cyanidin rhamnoglucoside. These examples will suffice to indicate the range of anthocyanins, but many other types are known.

The problem of the point or points of attachment of the sugar residues remains and this has been solved by three methods: in a very few cases by degradation (KARRER), by comparisons of properties with anthocyanidins of known structure synthesized for the purpose (Robinson and co-workers), and later by total synthesis of the anthocyanins themselves. As an example of the second method, cyanidin chloride dissolves in aqueous sodium carbonate to a pure blue solution, but chrysanthemin gives a violet-coloured solution that becomes blue on the addition of sodium hydroxide. The sugar residue in the monoglucoside covers up one hydroxyl group and so modifies the reactions; the question is, which hydroxyl group is concerned?



Numbering scheme



(IX)

We know from a different reaction that hydroxyls in positions 3′ and 4′ are free. Cyanidin chloride in weakly acid solution gives a very intense blue coloration on the addition of a trace of a ferric salt. This behaviour is shown only by synthetical anthocyanidins which have two hydroxyl groups in neighbouring (*ortho*) positions in the benzene ring. Chrysanthemin exhibits this ferric reaction and therefore the sugar is not attached to position 3′ or to 4′. When anthocyanidins containing one hydroxyl less than cyanidin were synthesized it was found that only

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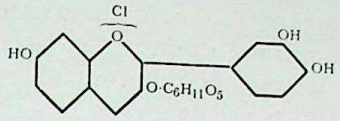
(IX) behaved like chrysanthemin towards alkalis; hence it became very likely that the hydroxyl in position 3 is not free in this monoglucoside. In other words, the indication was that chrysanthemin is cyanidin 3-monoglucoside (X). The probability was greatly increased when it was found



(X)

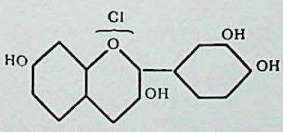
by similar comparisons that *all* the monoglucosidic anthocyanins should be anthocyanidin 3-glucosides.

It has been mentioned above that mecocyanin chloride is isomeric with cyanin chloride, and it is noteworthy that the behaviour of the two pigments in solutions of varying *p*H is quite different. The reactions of mecocyanin are, in point of fact, almost identical with those of chrysanthemin. Very careful hydrolysis splits mecocyanin into chrysanthemin and glucose and the pigment is accordingly chrysanthemin glucoside. As we know from the study of a large variety of synthetical pyrylium salts of known constitution that the properties in question are evidence that only one hydroxyl of cyanidin (in position 3) can be modified, it follows that mecocyanin should be a bioside and contain the group

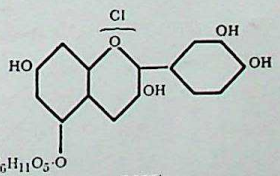
$$-O\cdot C_6H_{10}O_4\cdot O\cdot C_6H_{11}O_5$$

in position 3. This hypothesis was justified by synthesis (*see below*), and a similar argument applies to antirrhinin, which is cyanidin 3-rhamnoglucoside.

But cyanin chloride is evidently something different, and at first we thought it must be cyanidin 5-bioside because the salt (XI) gives colour reactions similar to those of cyanin. This seemed to be confirmed when the part-hydrolysis of cyanin was found to give a new cyanidin monoglucoside called cyanenin and this could only be cyanidin 5-glucoside (XII).



(XI)



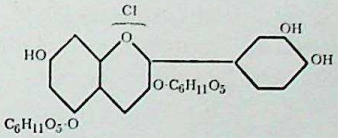
(XII)

Again this latter view was proved to be correct by synthesis.

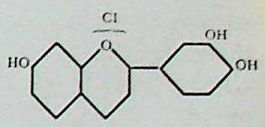
Closer study disclosed a new touchstone and a definite difference in behaviour between cyanenin and cyanin.

A very dilute acid solution of an anthocyanin cannot be preserved indefinitely in contact with air; the pigment is destroyed by oxidation. The process is hastened by the presence of catalysts such as iron salts, and it was noticed that the natural anthocyanins are far more stable in this respect than the anthocyanidins derived from them.

Using standardized conditions, including the addition of a minute relative amount of ferric chloride, it was found that the pigments could be divided into two classes: one group slowly destroyed during many hours, the other quickly destroyed in a few minutes. The substances of known structure in the former class contained no free hydroxyl in position 3, whereas this group was present in the substances of the latter class. Cyanenin (like cyanidin) was quickly destroyed, but cyanin (like chrysanthemin and mecocyanin) was very stable towards such aerial oxidation. The logical conclusion was that cyanin must be a 3-glucoside, and since it is also a 5-glucoside it should be cyanidin 3 : 5-dimonoglucoside (XIII). Then it was found that the colour reactions of (XIV) were like those of cyanin.



(XIII)



(XIV)

The correctness of this line of argument was eventually proved by synthesis, and similar methods showed that pelargonin, malvin (from *Malva sylvestris*, certain *Primulae*, and later many other natural sources), delphin, petunin (from petunias), and hirsutin (from *Primula hirsuta*) are also 3 : 5-dimonoglucosides of the respective anthocyanidins. In the case of pelargonidin derivatives, modification or elimination of the hydroxyl in position 5 is recognized by the exhibition of a yellow-green fluorescence in acid alcoholic solution. Pelargonidin and callistephin show no fluorescence, but pelargonin and pelargonenin (pelargonidin 5-glucoside obtained by part-hydrolysis of pelargonin) fluoresce brightly.

CHEMICAL BASIS OF COLOUR REACTIONS

In dilute faintly acid solution the anthocyanidins and anthocyanins are often converted into colourless *pseudo-bases* from which they may be

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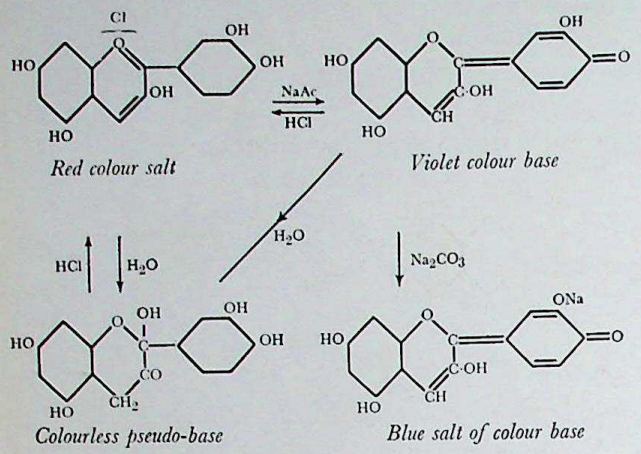
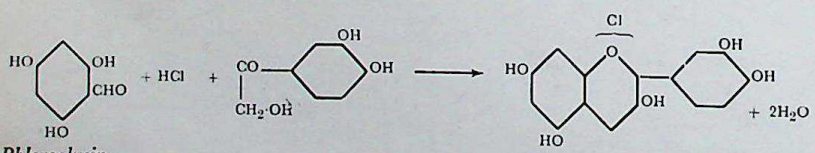
regenerated by the addition of acid. The changes in solution may be represented in the case of cyanidin:



SYNTHESIS OF THE ANTHOCYANINS

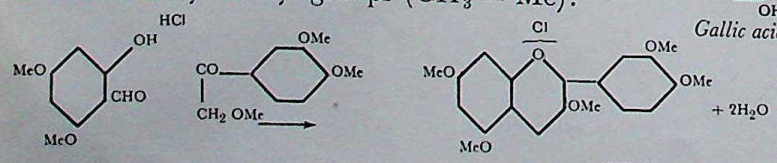
The method employed was an elaboration of a pyrylium salt synthesis discovered independently and simultaneously by Decker and Fellenberg and W. H. Perkin and the writer in 1907. A suitable hydroxyaldehyde is condensed with a substance containing the group $-CO-CH_2-$ by means of hydrogen chloride:

Thus we might expect to be able to synthesize cyanidin chloride as shown below:



Phloroglucinaldehyde

Phloroglucinaldehyde is a well-known substance, but when it is touched with hydrogen chloride it begins to condense with itself, and this process occurs more rapidly than the desired synthesis, so that phloroglucinaldehyde cannot be employed. In all such cases the organic chemist employs the device of protecting the reactive (or activating) groups, as in the familiar example of the industrial preparation of *p*-nitraniline. In the earlier work this was overdone and full protection was afforded by methyl groups ($CH_3 = Me$):



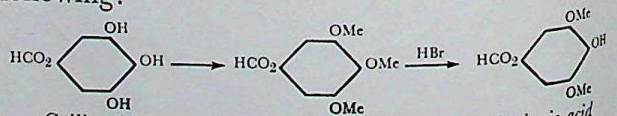
(XV)

This O-pentamethylcyanidin chloride (XV) was converted into cyanidin iodide by boiling concentrated hydriodic acid. The iodide was transformed into the chloride by means of silver chloride and the product shown to be identical with cyanidin chloride from cyanin and chrysanthemin. Pelargonidin and delphinidin were synthesized in a similar fashion, but it is obvious that partly methylated anthocyanidins such as malvidin could not be obtained in this way. The process used for the removal of the methyl groups was too vigorous and non-selective.

After considerable experimentation it was found that one benzoyl group is sufficient protection for the phloroglucinaldehyde, whilst the second component need not be protected at all. The resulting benzoylanthocyanidins can be hydrolysed by cold aqueous alcoholic sodium hydroxide, which also breaks open the central ring. Addition of hydrochloric acid reconstitutes the ring and provides the anthocyanidin. All the anthocyanidins have been synthesized in this way, the chief problem being the preparation of the appropriate second components.

Taking no account of the synthesis of the benzoyl group, benzoylphloroglucinaldehyde can be made from carbon in ten stages: $C \rightarrow CaC_2 \rightarrow C_2H_2 \rightarrow C_6H_6 \rightarrow C_6H_5NO_2 \rightarrow C_6H_4(NO_2)_2 \rightarrow C_6H_3(NO_2)_3 \rightarrow C_6H_3(NH_2)_3 \rightarrow C_6H_3(OH)_3 \rightarrow C_6H_2(OH)_3CHO \rightarrow C_6H_2(OH)_2(O{\cdot}COC_6H_5)CHO$. In the laboratory we start from purchased phloroglucinol, probably made by the above method from coal-tar benzene (C_6H_6). Our second starting-point in the case of malvidin is gallic acid, always prepared by the hydrolysis of naturally occurring tannin. It may be made from carbon by the eight stages: $C \rightarrow CaC_2 \rightarrow C_2H_2 \rightarrow C_6H_6 \rightarrow C_6H_5SO_3H \rightarrow C_6H_5OH \rightarrow C_6H_4(OH)CO_2H \rightarrow C_6H_2Br_2(OH){\cdot}CO_2H \rightarrow C_6H_2(OH)_3{\cdot}CO_2H$, in which the formation of sodium salts and acids from them is disregarded.

The remaining steps from gallic acid are the following:



Gallic acid *Syringic acid*

[This last step is a selective part-demethylation and the correctness of the constitution assigned to syringic acid has been rigorously proved.]

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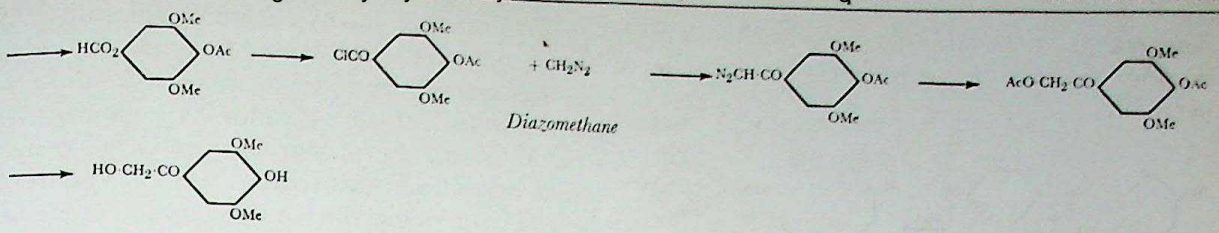
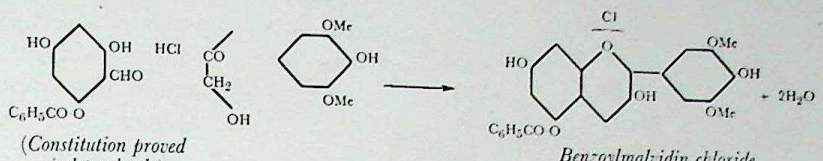
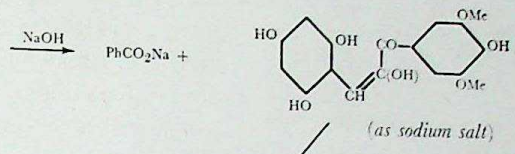
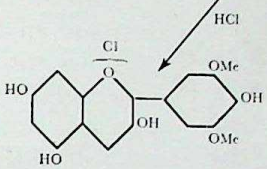


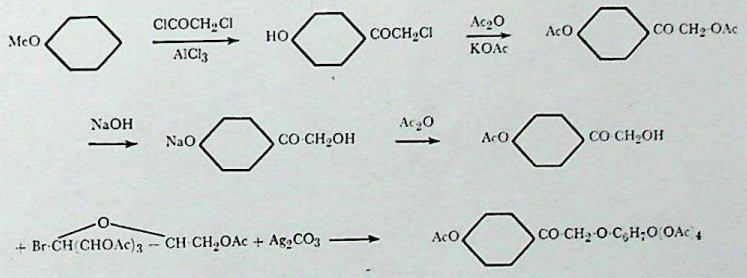
The synthesis succeeds in ethyl acetate solution in the cold:



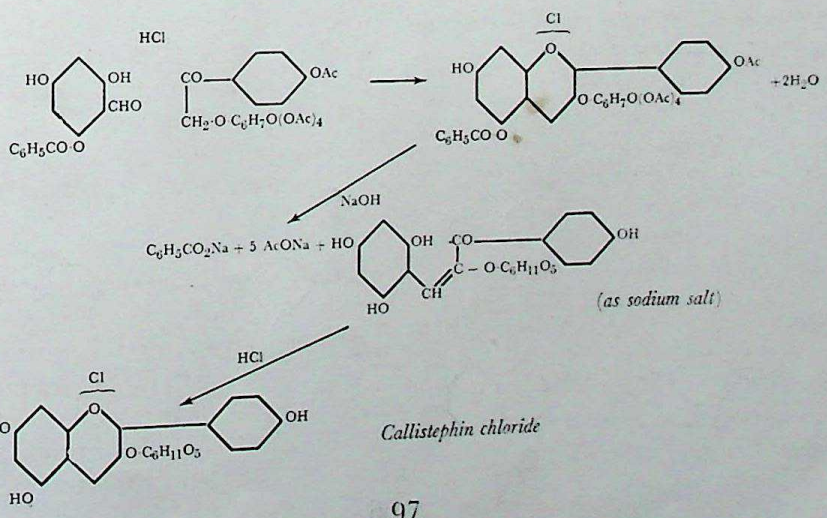




In applying such methods to the anthocyanins themselves, formidable experimental difficulties had to be surmounted because of the ease with which glucosides are hydrolysed by hydrochloric acid in the high concentration that must be employed. The preparation of the glucosidic components also presented obstacles, especially in the delphinidin and methylated delphinidin series. The simplest example is that of callistephin:



Then



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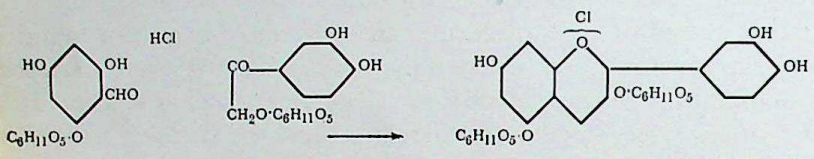
Similarly, by putting the glucose in the right places, the three other pelargonidin monoglucosides were synthesized and the work was extended to cover the whole field. The naturally occurring anthocyanins that have been artificially prepared are callistephin, pelargonidin 3-galactoside (which occurs in strawberries), chrysanthemin, idaein, delphinidin 3 - monoglucoside (in hydrangea flowers), delphinidin 3-monogalactoside, oenin, malvidin 3-monogalactoside, mecocyanin (which proved to be cyanidin 3-gentiobioside; the cellobioside, lactoside, and maltoside were made for comparison), antirrhinin (unpublished work), pelargonin, cyanin, delphin, and malvin.

It was later found that cyanin could be directly synthesized from unprotected components as below, but it is better to use the standard method:



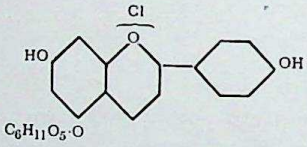
Cyanin chloride

A SURVEY OF ANTHOCYANINS

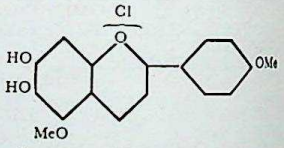
The possession of pure specimens of the chief anthocyanins enabled us to compare their reactions with those of solutions made by extracting plant material with 1 per cent. hydrochloric acid, and to devise procedure for the rapid examination of such extracts. Thus the anthocyanins present in a large number of species and varieties have been recognized, only a few flower petals or leaves being needed for the purpose. Substances known as co-pigments modify the colour reactions and other properties of the anthocyanins, but these disturbing influences can often be removed or, if not, allowance may be made for them. The chief co-pigments are tannins and anthoxanthins. A great variety of quick tests is available and these are applied both to the anthocyanin and the derived anthocyanidin. They include colour in acid solution in water and alcohol, colour reactions with sodium acetate, sodium carbonate, sodium hydroxide, the ferric reaction, a destructive oxidation test in about 5 per cent. sodium hydroxide, various special tests, and above all examination of the distribution ratios between 1 per cent. hydrochloric acid and immiscible organic solvents.

The use of amyl alcohol for this purpose was introduced by Willstätter. Anthocyanidins are completely extracted by this solvent from aqueous solution. Monoglucosides have distribution numbers (percentage of pigment that passes to the amyl alcohol under standard conditions) from 9 to 60, while diglucosides have low distribution numbers, from nearly zero to about 5. The method may be used for separation and purification purposes. Thus an anthocyanidin may be returned to 1 per cent. hydrochloric acid from an amyl alcoholic solution by the addition of benzene or light petroleum. Then it can be taken up again in amyl alcohol and so 'shuttlecocked' between the solvents until a sufficient degree of purity has been attained. Special mixtures have been devised for the purpose of differentiating the anthocyanidins. One mixture extracts much pelargonidin and peonidin, a little cyanidin, but no delphinidin, malvidin, or petunidin. Another extracts all the pelargonidin, peonidin, and malvidin, about half the cyanidin, some petunidin, and no delphinidin. Distribution methods also allow us to distinguish monoglucosides from rhamnoglucosides and these again from diglucosides.

As a result of this extensive survey only a few really novel types have come to light. The orange-red flowers of *Gesnera fulgens* contain gesnerin (XVI as chloride) which was synthesized for comparison. It is the only known anthocyanin not bearing oxygen in position 3:



(XVI)



(XVII)

A similar substance is *carajurin* (XVII, as hydrochloride), which was isolated from a rare cosmetic pigment used by the Indians of the Orinoco (A. G. PERKIN, CHAPMAN, and the writer, 1927). From what little we know of the method of preparation it is likely that it occurs in the plant, probably a *Bignonia*, in the form of a glucoside.

Various anthocyanins not yet isolated in substance have been recognized in plant material; for example, a pelargonidin 3-bioside occurs in the orange-red nasturtium flowers and a pelargonidin 3-rhamnoglucoside in the scarlet gloxinia.

Entirely new unidentified anthocyanins, as well as some of the types found in flowering plants, colour the young fronds of ferns; gymnosperms also have the power of producing these colouring matters. The point of entry into the vegetable kingdom has not yet been exactly located; in spite of statements to the contrary these pigments have

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not been found in bacteria, nor, so far as the writer is aware, in algae or fungi.

They may occur in almost all parts of plants: roots, stems, leaves, sepals, fruits, and flowers. The colour may be permanent, as in leaves of *Coleus*, or transitory, as in growing root-tips of certain saxifrages and in many young leaves. This wide distribution suggests a definite physiological function which, however, has not been elucidated. It may be protective (anti-oxidant?), but no satisfactory evidence of its nature has yet been garnered. Anthocyanins frequently appear at the site of injury of a plant, and autumnal reddening of leaves is another manifestation of these substances.

There is an overwhelming preponderance of cyanidin derivatives in young leaves, wound-anthocyanins, and in autumnally reddened leaves, and there is good statistical evidence that cyanidin may be regarded as the normal type. Pelargonidin requires a stage of reduction and delphinidin a stage of oxidation. It has been shown that the state of oxidation of the aromatic nuclei in cyanidin is the natural result of the theory that the substance is built up in the plant according to the scheme:

$C_6 + C_3 \rightarrow C_6 - C_3 + C_6 \rightarrow C_6 - C_3 - C_6$

Numerous representatives of the $C_6 - C_3$ types postulated as intermediates are known among natural products.

Flowers, especially garden flowers, are more highly specialized, and in them the anthocyanins have been differentiated and evolved to accommodate the requirements of reproduction (attraction of insects), climate, and horticulturists. Red flowers predominate in tropical regions and many are based on pelargonidin; even when delphinidin occurs the flower is often red. On the other hand, the higher alpine flora is characterized by a majority of blue flowers based on delphinidin.

Even so, cyanidin holds its own among the colours of flowers of all types. Of 530 species examined, 19 per cent. contain pelargonidin derivatives, 40 per cent. contain cyanidin or peonidin derivatives, and 50 per cent. contain delphinidin, malvidin, petunidin or hirsutidin derivatives. Of the 299 genera examined, 52 per cent. contained cyanidin derivatives. In families the percentage of cyanidin derivatives was 72, and in orders 80. This shows clearly the effect of differentiation; it should be noted that the more accessible and brightest flowers have naturally been studied first, and it is just these which have been most highly specialized.

NITROGENOUS ANTHOCYANINS

WILLSTÄTTER and SCHUDEL made a preliminary examination of betanin, the colouring matter of the beet, and showed that it contained nitrogen. Subsequently bracts of bougainvillaea afforded another member of the series (PRICE and the writer). Little is known of the chemistry of these pigments, but they are glucosides and their characteristic properties have been simulated by synthetical compounds containing an amino-group in the usual anthocyanidin molecule. The compositions of betanin and bougainvillaedin suggest that the anthocyanin molecule is attached to the amino-group of a protein amino-acid. Nudicaulin (PRICE, SCOTT-MONCRIEFF, and the writer), the yellow colouring matter of the Iceland poppy, also contains nitrogen and seems to be related to the group.

Nitrogenous anthocyanins have been found in five orders only, namely *Caryophyllales*, *Chenopodiales*, *Lythrales*, *Thymeleales*, and *Cactales*. It is probable, therefore, that the *Cactales* are not so remote from the four orders first named as is tentatively suggested by HUTCHINSON in his *Families of Flowering Plants* (1926).

NATURALLY OCCURRING SUBSTANCES RELATED TO ANTHOCYANINS

The anthoxanthins of the flavone (e.g. luteolin) and flavonol (e.g. quercetin) classes have already been mentioned. They occur in the plants as glucosides and represent an oxidized form of the central nucleus. There is no evidence that they are obtained from the anthocyanins by oxidation or that they are reduced *in vivo* to anthocyanins. Much more probably they are derived from common precursors by a forking of the roads. There is greater variety of constitution among the anthoxanthins than among the anthocyanins, and the two classes occurring together are more often than not unrelated.

It need occasion no surprise that the most common anthoxanthin, quercetin, is found alongside the most common anthocyanidin. It would be strange if this concurrence were not observed in a few cases, and the fact is not so significant as it would be if the types found together were uncommon.

More reduced substances are the leucoanthocyanins, the catechins, cyanomaclurin, peltogynol, etc. The term *leucoanthocyanin* has been used to denote very widely distributed substances that afford anthocyanidins when treated in air with hot alcoholic hydrochloric acid. There is little

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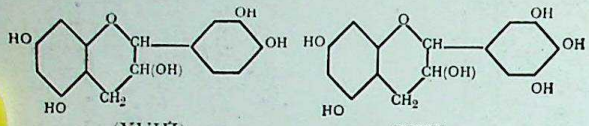
doubt that these are closely related to the anthocyanins and may be sources of the pigments under certain circumstances. That they are normal precursors is highly improbable. Some leucoanthocyanins give rise to pelargonidin and some to delphinidin, but the great majority give rise to cyanidin.

Catechins (XVIII), (XIX) represent the most reduced form of the anthoxanthin-anthocyanin types and APPEL and the writer have been able to oxidize Gambier-catechin (XVIII) to cyanidin. The process was indirect and involved methylation, oxidation by bromine to a methylated bromo-cyanidin, and then combined demethylation and elimination of bromine under the influence of hot hydriodic acid. This is perhaps the easiest way to acquire a supply of cyanidin:



(XVIII) (XIX)

GENETICS OF FLOWER COLOUR

Only a brief reference to this subject can be made since it demands separate treatment. The methods developed for the purposes of the survey of anthocyanins have been found invaluable in making the large number of analyses required in connexion with breeding experiments.

The genes responsible for variations of flower colour have been identified in many genera, and some important deductions have been drawn in regard to the mechanism of anthocyanin synthesis in the plant. For example, a study of *Dahlia* by LAWRENCE and SCOTT-MONCRIEFF has made it very probable that the anthocyanins and anthoxanthins are derived from two common precursors, one of which is plentiful and the other in limited supply.

The writer and LADY ROBINSON have been privileged to participate in one of these investigations, namely that on Sweet Peas (BEALE, ROBINSON, ROBINSON and SCOTT-MONCRIEFF). The figures opposite, reprinted from the *Journal of Genetics* (1939), illustrate some of the main types and incidentally form an epitome of the causes of variation of flower colours. The larger part of the flower is called the standard and the lower smaller section represents the wings.

(1) Purple, hooded, dark wing. The anthocyanin is based on delphinidin; it is diglucosidic and methylated (petunidin and malvidin).

(2) Red, hooded, dark wing. Anthocyanin based on cyanidin and largely peonidin diglucoside.

(3) Salmon, hooded, dark wing. Anthocyanin, pelargonidin diglucoside.

These three illustrate differences due to the nature of the anthocyanin.

(4) Purple, light wing. Anthocyanin as in (1), but much co-pigment and little anthocyanin in the wings.

(5) Copper or maroon, standard and wings identical, no co-pigment present in wings. This type is found in purple, red, and salmon flowers, the example given being based on delphinidin. The absence of co-pigment is associated with ready bleaching in sunlight and is due to a specific gene.

(6) Mauve, hooded, dark wing. Anthocyanin based on delphinidin. Much co-pigment and little anthocyanin throughout.

(7) Purple, dark wing. Anthocyanin based on delphinidin, co-pigment in wings.

(8) Dull, dark wing. As (7) but the cell-sap has a higher *p*H (more alkaline).

(9) Red, dark wing. As (2) but lacking factor H (hooded) and co-pigmented in the wings.

(10) Dull red, dark wing. As (9) but the cell-sap has a higher *p*H.

It should be noted that many factors, e.g. 'hooded', are associated with changes in anthocyanin concentration, in this example with an increased content. Thus (1) and (2) contain relatively more anthocyanin than (7) and (8) and (9) and (10) respectively.

The writer cannot close without acknowledging his deep debt to enthusiastic collaborators, among whom DRS D. G. PRATT and W. BRADLEY, PROFESSORS A. ROBERTSON and A. R. TODD, must be specially mentioned in connexion with synthetic work. LADY ROBINSON took a leading part in the survey of anthocyanins and leucoanthocyanins and MISS R. SCOTT-MONCRIEFF (MRS MEARES) has been a pioneer in the field of genetics of flower colour. DR J. R. PRICE worked on nitrogenous anthocyanins and has notably extended the survey.

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The substance of heredity

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C. D. DARLINGTON

'Like father, like son'—but why and how? Scientists have long had some inkling of the general mechanism of heredity, but during the last few years a wealth of detailed and precise information on the subject has been acquired. Dr Darlington here reviews recent work and shows that the transmission of hereditary characters is ultimately a chemical process.

Perhaps the simplest, and the earliest, view of heredity is that of a *force*, a force which interacts with that of the environment to give the organism as we know it. The effectiveness of this force is expressed in the proverb that you cannot make a silk purse out of a sow's ear. A second view, likewise early and originally simple, is that heredity is a *law*, the law that like begets like. Both these views find their place in recent genetics. The first appears as JOHANNSEN's formal and perhaps mystical concept of the genotype interacting with the environment to give the phenotype or visible character. The second appears as MENDEL's laws of segregation and recombination. But there has been a third view of heredity derived not from popular belief but from philosophy, namely that heredity is a *substance:* that its force and its laws are merely the properties of the *genitalia corpora* of the Greek materialists. It is to this last view that genetics has come in the last twenty years. The substance is the chromosomes, the laws are the mechanics, and the force is the chemistry of these bodies.

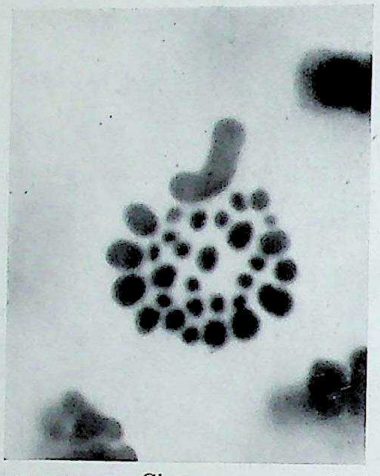

FIGURE 1 – *Chromosomes at mitosis in a male grasshopper,* Leptophyes punctatissima. *There are thirty ordinary chromosomes, and one X chromosome at the top.* (× 2,400)

What, then, are chromosomes? To understand them we must recall that the whole body of the plant or animal is divided into compartments or cells, each of which contains a living unit. Blood-corpuscles, pollen grains and eggs are easily separated cells, whereas tissues like muscle and brain are masses of cells closely bound together. Each of these cells is governed by a small globular body which we call the nucleus. As the plant or animal grows its cells divide, and this division or mitosis naturally entails the division of the nucleus. When the nucleus divides it resolves itself into a number—constant for any particular individual —of rod-shaped bodies which are the chromosomes (figure 1).

Every cell in the body keeps its fixed number of chromosomes because when the nucleus divides each of the chromosomes splits lengthwise and its identical halves pass to the opposite daughter-cells. Here we begin to see the mechanism of heredity at work, since this process of division maintains complete uniformity in the controlling substance of heredity throughout the body.

The number of chromosomes is not only uniform. It is usually even. The meaning of this becomes clear when we watch the formation of the germ-cells—eggs and spermatozoa. In the parent-cell, which divides to give the germ-cells, the chromosomes associate in pairs, and by tracing their history backwards we can prove that one member of each of these pairs is derived from the mother and one from the father. Every plant or animal therefore has a double heredity. Furthermore, the partners separate without themselves dividing, so that the eggs and sperm get only half the number of chromosomes: the *diploid* number, as we say, is reduced to the *haploid*. And when the egg is fertilized by the sperm a new individual is created with the diploid number again.

This individual is new in an hereditary or genetic sense because it has a new combination of chromosomes different from that of either of its parents. Indeed, since each pair of chromosomes can break and recombine, or 'cross over' at many places, and at different places in different parent-cells, each of the progeny is likely to be different from every one of its brothers or sisters (figure 2).

Let us see how this shows itself in practice.

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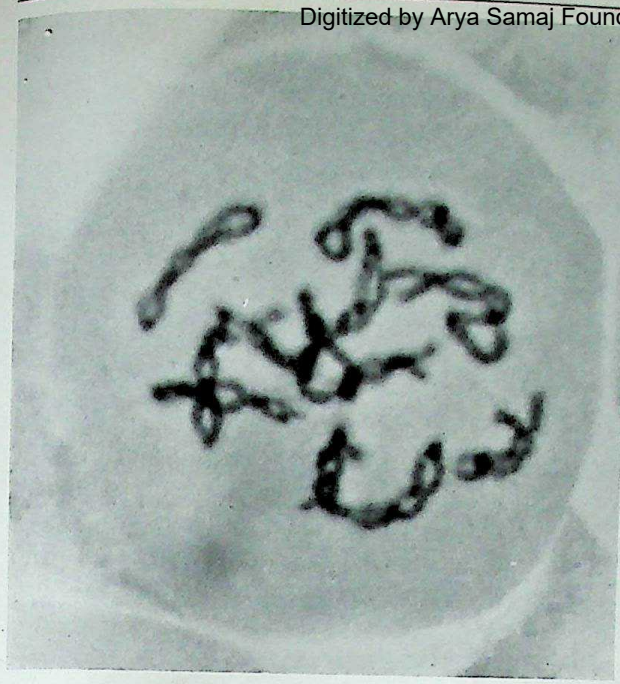

FIGURE 2 – *Twelve paired chromosomes in a pollen mother-cell of a lily*, Fritillaria chitralensis. *The points where the loops meet mark the positions of crossing over between the partners.* (× 1,600)

Most hereditary differences, such as height and skin colour in man, are determined by the interaction of all the chromosomes, which differ in many minute respects. But often we have large and simple differences. These were the ones BATESON used in his pioneer work on the breeding of poultry. He found that black and white breeds crossed together gave either black, 'blue,' or white progeny. But when a second generation was raised by crossing two blues they would never breed true. They always produced black, blue, and white in the proportions of 1 : 2 : 1. There was a clean separation or segregation of the three types. When Mendel had first obtained this kind of result he supposed that the first generation had mixed hereditary factors *Bb* (black—white). It therefore formed equal numbers of germ-cells with *B* and *b* and gave progeny with the factor combinations *BB : Bb : bb* in the proportions 1 : 2 : 1. Now we can see that the chromosomes exactly fulfil these conditions by their pairing and division in the germ mother-cells.

One of the most important hereditary differences is that of sex itself, and since the segregation is so sharp and the ratio of approximate equality between males and females so general, it is natural to suppose that here we have a single hereditary difference. For example, if females were all *XX* and males all *Xx*, then the progeny from the inevitable cross *XX* by *Xx* would be half of each sex. In fact, we find that all mammals have a pair of chromosomes which we call *XX*, or the sex chromosomes, in the females, while in the males there is only one *X*, which pairs with a very small partner differing from the large *X* in simply lacking about half its length. The little one we call *Y*. The male is a male because he has less heredity [6]. This is even clearer in many insects where there is no *Y* chromosome at all and the male is just one chromosome short (figure 1).

This system of sex determination has some striking consequences in heredity. Take the tortoiseshell cat. She has a strange tale to tell. To begin with, she is always a female. When she is crossed with either a black or a yellow tom, her male offspring are black and yellow in equal numbers. The father makes no difference. Clearly the tortoiseshell is mixed for black and yellow, and the factors or *genes* for black and yellow lie in the *X* chromosome and not in the *Y*. The male therefore cannot have the mixed heredity necessary for the tortoiseshell patching.

What makes one gene determine the black colour while its alternative determines the yellow? We cannot yet give the answer, but in trying to give it we have gone some way towards understanding the chemistry of the chromosomes and the genes.

To begin from the inside. We find the chromosome consists of a protein fibre not entirely unlike hair or silk [1]. It depends on the peptide chain linkage —C—C—N—. On this framework are fixed at intervals the active groups which we know as genes. The genes regulate amongst other things the division cycle of the nucleus, and this they do by a very definite and uniform chemical device in all organisms. They attach to themselves series of flat plates, the nucleotides of thymonucleic acid, which polymerize in columns parallel with the slender polypeptide fibres. The plates are spaced at exactly the same distance apart as the atoms in the peptide chain—3·4 Ångström units, as ASTBURY found from X-ray analysis (cf. this Journal, Vol. I, pp. 70–73). These well-fitting columns are responsible for the two primary properties of chromosomes and genes, namely coiling and reproduction. The coiling of the chromosome is what enables it to contract from the fine dispersed thread of the working nucleus to the rod which manœuvres itself into position for regular distribution when the cell

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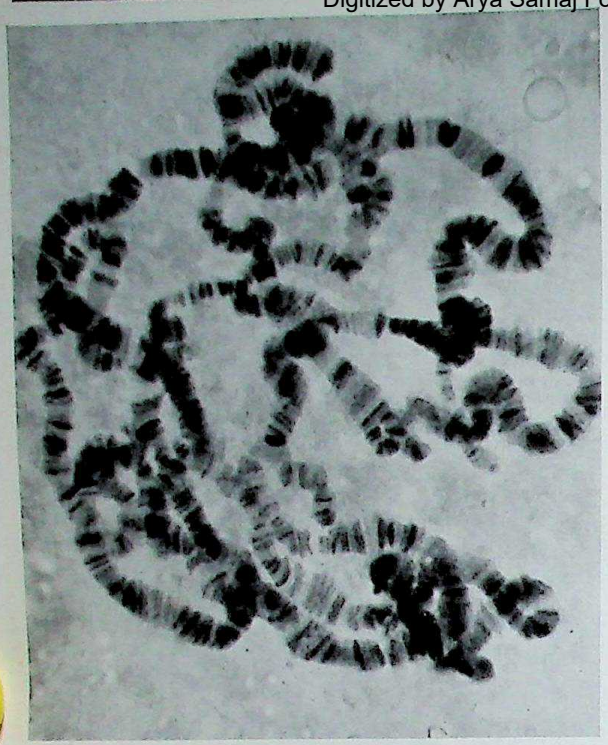


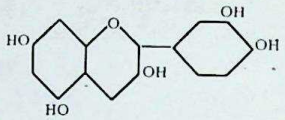
FIGURE 3 – *Resting nucleus of a salivary gland cell in the fly* Drosophila melanogaster. *The genes have undergone eight cycles of reproduction and so occur as series of flat plates each with 256 genes. The larger genes make deeper staining bands.* (× 1,500)

divides. The reproduction is the basis of heredity, and indeed of life, for without identical reduplication any living system would quickly break down (figure 3).

Nucleic acid renders a further invaluable service—it makes the chromosomes visible. This it does in two ways: by absorbing dyes differentially and also by absorbing ultra-violet light differentially, a method of study developed by CASPERSSON (cf. [2]), figure 4. We can therefore very easily see what is happening to the nucleic acid. We find that some parts of the chromosomes throw off their coat of nucleic acid when they re-form the nucleus at the end of the cell-division. It is then stored in a special body, the nucleolus, and in a special reserve form with a different sugar radicle. Other parts do not (figure 5), and these we find are the parts that are doing no work in the cells in question. There are some blocks of genes, or even whole chromosomes, that rarely seem to work, and we find that such blocks can be broken off by X-rays, or otherwise lost, without the organism being much the worse for it. If we enable cells with such inert chromosomes to divide at freezing-point we see these chromosomes in a starved condition. They are starved of nucleic acid and the gene string of the chromosome is naked and almost unstained (figure 6). In extreme cases it then fails to coil and to reproduce properly [3].

Here we see a little of how the machinery of heredity works from the inside. From the outside, the task of inquiry is bigger, more laborious, and more elaborate. A few instances will show how the problem is being tackled (cf. [5]).

The chief flower colours rest on a basis of red and blue pigments, the anthocyanins, whose detailed structure and variations have recently been revealed by ROBINSON at Oxford (see p. 92). The simplest of these pigments is a glycoside of cyanidin which is the usual basis of leaf and stem colours and seems to be derived from two hexose units and one triose arranged as follows:



The great variety of flower pigments has apparently been developed from this basic type by oxidation, reduction, methylation, and addition of a second sugar radicle, at various positions. Each of these changes can be determined in the plant by the mutation of a single gene. Study of the effects of combinations of different genes in various plants has enabled LAWRENCE and PRICE [7] to work out the order in which the several genes act during the process of formation of these pigments from sugar in the cell. Their work supports the view that the products of the different genes interact during development sometimes by co-operation, sometimes by competition, sometimes even by interference, and that by determining in this way one another's activity or

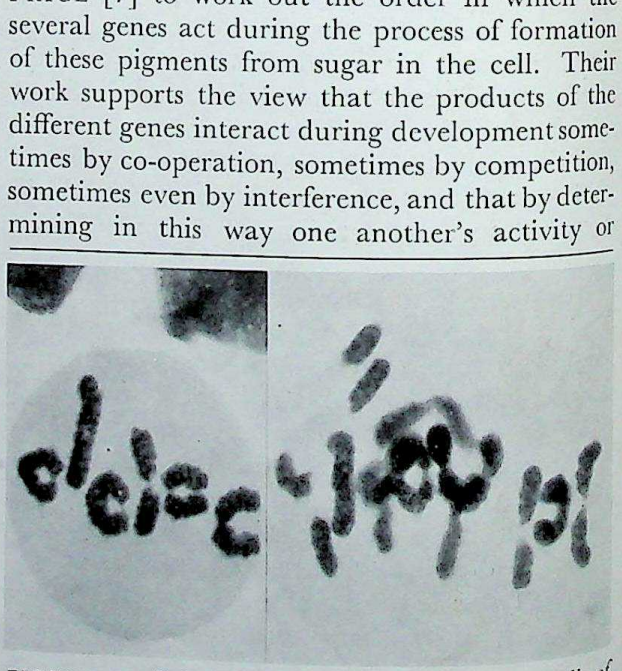


FIGURE 4 – *Paired chromosomes in pollen mother-cells of two species of* Tradescantia. *Right: six pairs in a cell fixed and stained in acetic orcein. Left: twelve pairs in a living cell photographed with ultra-violet light.* (× 1,000)

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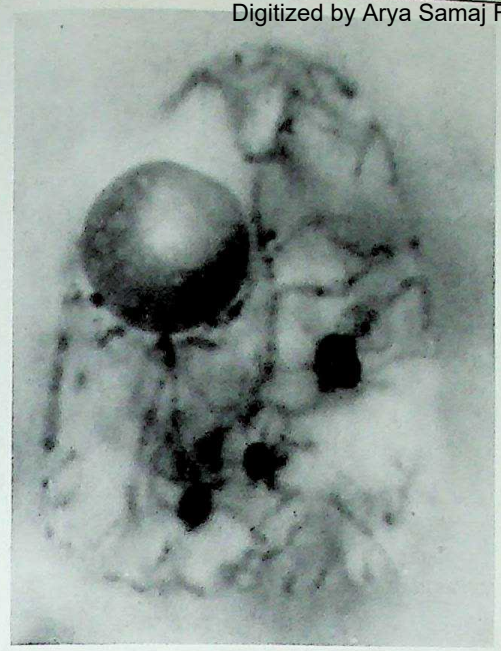

FIGURE 5 – *Embryo-sac mother-cell of* Fritillaria pudica *showing three condensed masses of inert chromosome charged with thymo- or desoxyribose-nucleic acid and the large faintly stained sphere containing the reserve of ribose-nucleic acid. The differentiation is produced by Feulgen's staining method which depends on Schiff's aldehyde reaction.* (× 2,400)

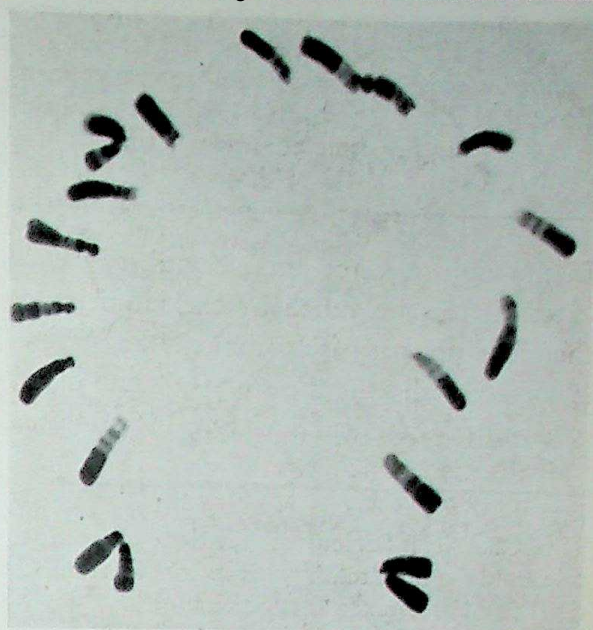

FIGURE 6 – *Starved chromosomes reduced by cold treatment in the pollen grains of* Fritillaria pudica. *The pale bands are inert segments.* (× 1,800)

inactivity they jointly regulate the whole process of development.

Most gene differences depend for their degrees of expression on variations in external conditions. Changes of temperature or diet will alter this expression and sometimes entirely inhibit it. For example, there is a gene change known in the fruit-fly *Drosophila* which prevents the development of antennae under normal conditions of growth. But when the grubs are amply supplied with vitamin B_2 the 'antennaless' flies become indistinguishable from the normal wild type [4]. Thus evidently the genetic difference concerned in this case depends on ability or inability to do something that is done by the molecule of vitamin B_2. We have equated the action of a specific gene with that of a specific enzyme. Although it is going to be more expensive to test the influence of nutrition on the expression of hereditary differences in man, we can hardly doubt that diet will prove as effective in man as in the fly.

Thus from both ends we see the machinery of heredity being pulled to pieces. It is chemical machinery, but the molecules that are concerned are enormously varied in shape and size. Some of the systems they work are most easily studied in the breeding-bottle, others in the test-tube, and others again under the ultra-violet or electron microscope. Gradually by these means we shall discover how they all work together. And, when we do, we shall find that while the old distinction between the living and the non-living is clear enough, the distinction between chemistry and biology will have become merely one of technique.

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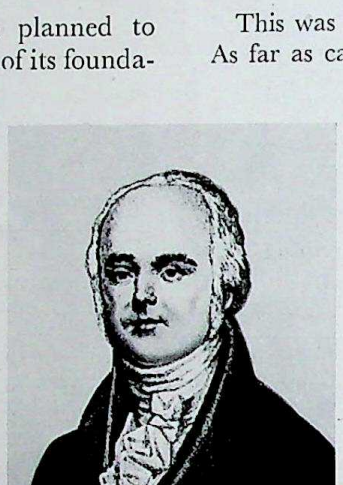
Some eighteenth-century chemical societies

JAMES KENDALL

In the eighteenth century, chemistry was a fashionable pursuit in Britain, and was cultivated at least as much by the inquiring amateur as by the professional scientist. It is therefore not surprising that at this period chemical societies began to take shape. Professor Kendall tells the story of some of these early societies, including the University of Edinburgh Chemical Society, which he shows to have been in existence as long ago as 1785.

The Chemical Society of London planned to celebrate the hundredth anniversary of its foundation in 1941, since its official records state that 'on the 23rd of February, 1841, twenty-five gentlemen interested in the prosecution of Chemistry met together at the Society of Arts to consider whether it be expedient to form a Chemical Society.' Formal celebration of this centenary has been, of course, postponed owing to the war, but in view of the impression that is still prevalent that the Chemical Society of London was 'the first chemical society in the world,' it appears opportune now to present, in brief, the information available regarding a number of other chemical societies which were in existence even before the conclusion of the eighteenth century.



James Woodhouse.

In very olden days, chemists did not forgather merely as chemists; they merged themselves in broader organizations such as the Royal Society. The 'chemical revolution' which had its real beginning with the work of JOSEPH BLACK and which culminated in the overthrow of the phlogiston theory by LAVOISIER aroused, for the first time, a popular interest in the special science of chemistry. Until recently, world priority among the chemical societies that resulted therefrom was by general agreement conceded to the Chemical Society of Philadelphia, founded by JAMES WOODHOUSE in 1792. The distinguished chemical historian EDGAR F. SMITH [7], late Provost of the University of Pennsylvania, may be quoted in this connection:

> This was the first chemical society in the world. As far as can be learned, Woodhouse was its first and only president. This society lived about seventeen years. Its members favoured Lavoisier's doctrine of combustion. The minutes of the society have never been found, although diligent search has been made for them.

Copies of a number of publications of the society, however, have been preserved, and reproductions of the title-pages of two of them are shown on p. 107. The oration of THOMAS P. SMITH was purely historical and did not contain any new experiments, but ROBERT HARE's memoir on his invention of the oxy-hydrogen blowpipe represents a real landmark in scientific discovery.

The title of the Chemical Society of Philadelphia was not questioned until 1935. In April of that year, the Edinburgh University Chemical Society met to celebrate its Diamond Jubilee, being under the impression that it was founded only sixty years previously, and I was requested to prepare a speech for the occasion. Reading SIR WILLIAM RAMSAY's biography of Joseph Black to obtain some historical material for this oration, I came across the statement [6] that, among the correspondence of Joseph Black, Ramsay had discovered a sheet of paper, of which only the date, 1785, was in Black's handwriting, entitled 'List of the Members of the Chemical Society.' Ramsay remarked regarding this as follows:

> This may have been a society of persons residing in Edinburgh interested in Chemistry, but is more

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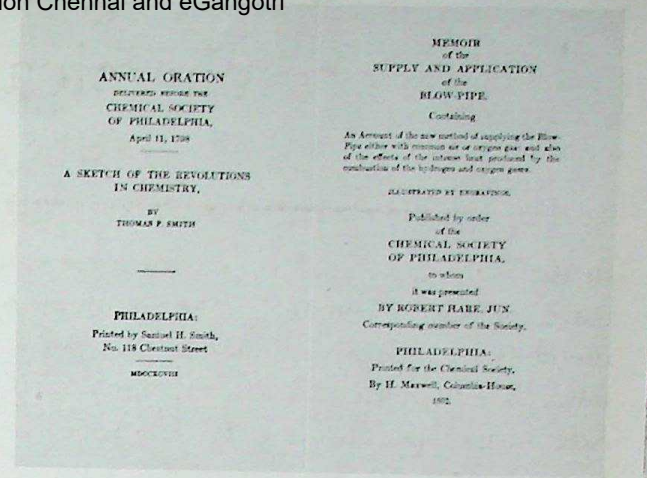
likely to have been a general society. The only name that I can recognize is that of Dr Thos. Beddoes [the founder of the Pneumatic Institute and the 'discoverer' of Sir Humphry Davy]; the names themselves would indicate that their possessors belonged to all parts of the kingdom.

The complete list of names—fifty-nine in all—is reproduced below:

John Webster	Hen. N. Ward	J. Alderson
Wm. Scott	Morgan Deasy	J. McElwaine
— Halliday	H. Pache	T. Gill
Jas. Forster	Jno. Gay	T. Willson
Sam. Black	Tho. McMorran	Frs. Montgomery
Jno. Black	Adam Gillespy	Thos. Swainson
Jas. Plumbe	Thos. Burnside	Archd. Webb
Wm. Johnston	Corn. Pyne	J. Crumbie
Thos. Clothier	J. Unthank	Geo. Marjoribanks
Henry Johnston	J. Barrow	T. Grieg
Peter Gernon	J. Donavan	J. Parr
Robt. Ross	Saml. Macoy	Alex. Stevens
L. van Meurs	G. Tower	Wm. Symonds
(amteemann batavis)	J. Sedgwick	Thos. Beddoes
Hugh Brown	T. Skeete	J. Thompson
John Boyton	Wm. Robertson	G. Kirkaldie
Edw. Fairclough	J. Sprole	J. Carmichel
Bicker McDonald	Thos. Cooke	Nich. Elcock
F. Galley	Thos. Edgar	Richd. Gray
An. Mann	Guyton Jolly	J. Hayle

The idea struck me that an examination of the register of students at the University of Edinburgh at that period might identify more of the names in the above list. This register was accordingly consulted, and within a quarter of an hour it was established that no fewer than fifty-three out of the fifty-nine were students attending Black's class in chemistry at Edinburgh University during the years 1783–87. Thanks to the kindly zeal of DR ALEXANDER MORGAN, five of the missing six were also subsequently traced as registered students of Joseph Black between 1780 and 1788. The only name on the list definitely unlocated is that of Peter Gernon.

In the light of the above discoveries, it became my pleasant duty to inform my fellow-members of the Edinburgh University Chemical Society at their 'Diamond Jubilee luncheon' that they had been called together under false pretences, since they were actually celebrating their Sesquicentenary! For it is quite plain that the society of 1785 was not, as Ramsay surmised, a *general* society. It was, on the contrary, a society consisting of those members of Black's class with a special interest in chemistry—in other words, it was the Chemical Society of the University of Edinburgh. How long it survived after 1785, or how long it existed prior to 1785, we have at present no knowledge, but now that the origin of its membership has been fixed the possibility, noted by Ramsay, of locating 'some one of their descendants in possession of some record of its proceedings and history,' is clearly much more likely of realization.



ANNUAL ORATION
DELIVERED BEFORE THE
CHEMICAL SOCIETY
OF PHILADELPHIA,
April 11, 1798

A SKETCH OF THE REVOLUTIONS
IN CHEMISTRY.

BY
THOMAS P. SMITH

PHILADELPHIA:
Printed by Samuel H. Smith,
No. 118 Chestnut Street
MDCCXCVIII

MEMOIR
of the
SUPPLY AND APPLICATION
of the
BLOW-PIPE.
Containing
An Account of the new method of supplying the Blow-Pipe either with common air or oxygen gas: and also of the effects of the intense heat produced by the combustion of the hydrogen and oxygen gases.
ILLUSTRATED BY EXPERIMENT.
Published by order
of the
CHEMICAL SOCIETY
OF PHILADELPHIA,
to whom
it was presented
BY ROBERT HARE, JUN.
Corresponding member of the Society.
PHILADELPHIA:
Printed for the Chemical Society,
By H. Maxwell, Columbia-House,
1802.

Nineteen out of the fifty-nine members are on the list of medical graduates of the University of Edinburgh between the years 1784–90. This list also gives the nationality in each case, and it is interesting to find that, of the nineteen, only three were native Scots, three English, and the residual thirteen all Irish! Joseph Black was himself, of course, of Belfast ancestry, and the proportion of Irish students in the Scottish universities has always been significant; but such a preponderance as this is very surprising. Whether its Irish element was responsible for the temporary disruption of the society (it is ominous that Bicker McDonald and J. Unthank were both Hibernians) is a question that, perhaps just as well, we are not in a position to press.

There were, however, at least three other chemical societies existent in Scotland prior to 1801 [1], [2]. The first of these flourished in the University of Glasgow as early as 1786; among its members were JOHN MACLEAN, CHARLES MACINTOSH and JOHN THOMSON. John Maclean later became the first Professor of Chemistry in the College of New Jersey (now Princeton University), and it is stated in his biography [4] that:

> at the University he was, while yet a lad, a member of the Chemical Society, a club which appears to have met at the University, with the permission of the College authorities, if not under the oversight of the Professors. The members submitted, for the consideration of the Society, papers and essays upon various matters connected with the object of their association, and some of these papers seem to have foreshadowed the eminence which the authors of them attained in after life, as proficients in the art of Chemistry.

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One of seven papers which it read before the society, dated 29th March [1786?], contains a reference to DR WILLIAM IRVINE, Lecturer in Chemistry at Glasgow University. Irvine died in the summer of 1787, and on 18th October of that year DR A. EASON of Manchester remarks in a letter [3] to Charles Macintosh (the inventor of the waterproof coat):

'How does your chemical society get on? I am afraid, badly, since poor Irvine is gone. However, you must keep it up.'

It was presumably this same society to which reference is made in the biographical notice of Dr John Thomson, Professor of Medicine in the University of Edinburgh, by his son Dr William Thomson [8]:

> At the beginning of the winter session of 1788–89, Mr John Thomson went to Glasgow to attend the medical classes. Besides prosecuting the study of anatomy with ardour, he attended the lectures of Dr Cleghorn, who was lecturer on chemistry in the college, an office which had been successively held by Cullen, Black, and Irvine. He also joined a chemical society, which contained several members who afterwards attained great eminence as practical chemists. The doctrines of Lavoisier had just been made known, and gave much interest to the proceedings of young and ardent cultivators of chemical science, among whom it may be supposed that they found a readier reception than among those who, before adopting the new doctrines, had previously to unlearn the old.

A second chemical society, however, was founded in Glasgow in 1798; its president in 1800 was WILLIAM RAMSAY, grandfather of Sir William Ramsay. The minute book of this society for the period 8th October, 1800, to 25th March, 1801, is now in the possession of the Royal Philosophical Society of Glasgow [10]. It consists almost entirely of a record of experimental work by the society, apparently carried out at its meetings, which were held generally more frequently than once a month.

Simultaneously we find Dr John Thomson [9] in Edinburgh converting a Natural History Society, probably at the Royal College of Surgeons, into a Chemical Society, of which Lord Brougham and Lord Lauderdale were members. In a letter to his friend Mr Allen, dated 12th June, 1800, he wrote:

> Lord Lauderdale and I made the galvanic experiment last week, and I exhibited it to the Society on Saturday. We are getting tubes with gold wires and glass stoppers to try its effects on caustic liquids, and we are getting a very broad plate of zinc made, to try whether the increase in power be in proportion to the increase of surface. In that case his Lordship's whole service of plate will be converted into a galvanic battery!

There were, thus, before the end of the eighteenth century, no fewer than four chemical societies instituted in Scotland—a truly admirable manifestation of the clan spirit. It is, furthermore, not unreasonable to regard the Chemical Society of Philadelphia as a daughter society of that at Edinburgh in 1785. The medical school of the College of Philadelphia (now the University of Pennsylvania) was instituted in 1765 under strong Edinburgh auspices, and the coat of arms of the University of Edinburgh is still to be seen above the entrance to one of its original buildings. JOHN MORGAN, who first taught chemistry there, and BENJAMIN RUSH, who succeeded him in 1769 as the first full-time Professor of Chemistry in America, were both students of Joseph Black in Edinburgh. With such an intimate connection between the two centres, the existence of a chemical society at Edinburgh University, sponsored by Black, would certainly be a matter of common knowledge in the College of Philadelphia, and when James Woodhouse (then a young man of 22) founded the Chemical Society of Philadelphia in 1792 he may quite plausibly be pictured as following, consciously and deliberately, in the footsteps of Joseph Black.

In 1937, after noting this galaxy of eighteenth-century chemical societies in Scotland [2], I ventured to conclude with the provocative statement that it would be interesting to ascertain when the custom first spread into the degenerate South. This challenge was answered two years later by PROFESSOR J. C. PHILIP, who informed me that a chemical society met in London as early as 1782. The only direct reference to this society is in the Journal of JOHN PLAYFAIR, Professor of Natural Philosophy in the University of Edinburgh [5]:

> 'Chemistry is the *rage* in London at present. I was introduced by Mr B. Vaughan (with whom I became acquainted in Edinburgh while he studied at the University there) to a chemical society, which meets once a fortnight at the Chapter Coffee-house. Here I met Mr Whithurst, Dr Keir, Dr. Crawfurd, and several others.'

Playfair goes on to record how he also saw DR PRIESTLEY, 'who has made so great a figure in the world.' Priestley was then 'particularly engaged in some experiments to prove that inflammable air is the same thing with phlogiston,' but Playfair was too canny a Scot to be convinced.

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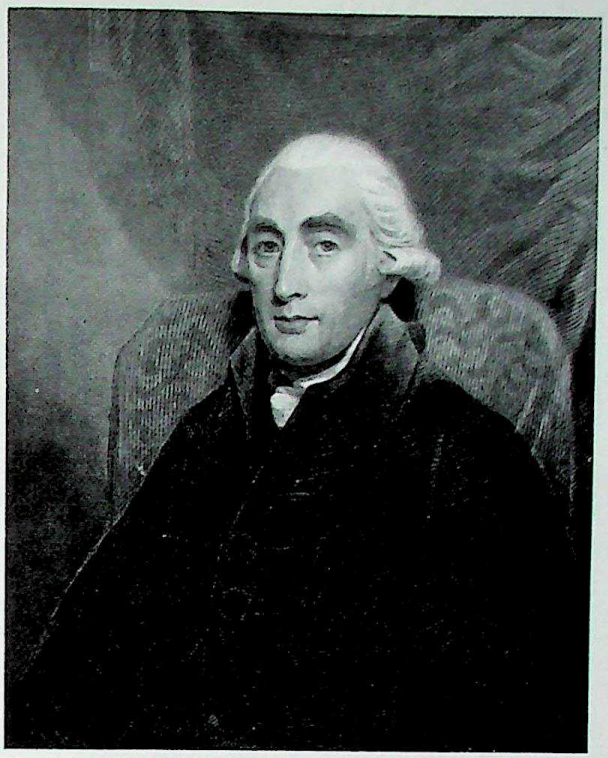
Are we to regard this London Society of 1782, as displacing the Edinburgh University Chemical Society, existent in 1785, from its title of 'the first chemical society in the world'? Personally, I do not think so. It will be noted that the London society to which the Edinburgh professor was introduced had a suspiciously Caledonian flavouring—Mr B. Vaughan was certainly one of Black's students, and two of the other three members named by Playfair are obvious Scots. Is it not likely that this also constituted an offshoot—the 'London branch'—of Joseph Black's original society, the exact date of the founding of which is unknown?



Joseph Black. *G. Bell & Sons*

In any case, the wealth of material that has already come to light encourages the hope that further research will reveal the existence of still more chemical societies of the Black-Priestley-Lavoisier era. It appears probable that one such society flourished in Manchester before 1787, since Dr Eason's letter to Charles Macintosh of that date, already quoted, contains the sentence: 'We intend another volume of our transactions by next spring.' If this article inspires examination of local records of the period leading to additional discoveries, its purpose will have been achieved. Meanwhile, congratulations may be extended to the present Chemical Society of London as the first chemical society in the world to complete a hundred years of continuous existence. May the triumphant celebration of its centenary be witnessed in the very near future!

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Plastics and their application

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SIR EDWARD APPLETON

No synthetic substances find wider or more diverse applications than plastics, and their usefulness continues to increase. Sir Edward Appleton discusses the structure and properties of some of the principal types, and his illustrations reveal their adaptability for surprisingly various purposes. Electrical apparatus, brushes, gun-turrets, boats, and even gear wheels —these are a few of the articles made wholly or partially of plastic materials.

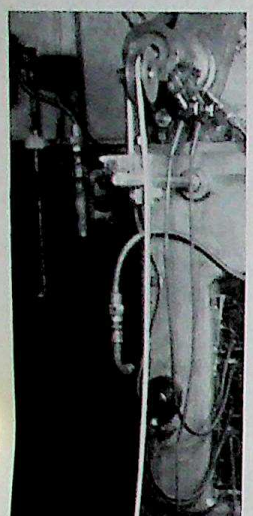


FIGURE 1 – *Test extrusion of soft polyvinyl chloride sheathing.*

War-time lends a special urgency to the task of reducing the number of operations in manufacture. Some manufactured articles are of intricate shape and, to produce them from solid materials, much cutting, turning, drilling, and grinding may be needed. It is for such articles as these that plastics, if materially suitable, can be used to best advantage, for, essentially, their shape is then determined by a single operation.

The plastics industry, which has arisen only in relatively recent years, depends on the use of organic materials which, usually by the application of heat, can be rendered plastic and thus formed to a desired shape, which is retained when the plasticizing agency is withdrawn. The materials seldom occur naturally, and generally are entirely synthetic. As examples one might refer to the resins made by the interaction of phenol (carbolic acid) and formaldehyde or of urea and formaldehyde. Another group of substances is made by polymerization, i.e. by the union of small molecules of liquids, or even gases, to form large molecules representing plastic solids. Of such origin and type are polystyrene and polyvinyl chloride. Other plastics, such as cellulose nitrate and cellulose acetate, made by the action of nitric or acetic acid on cellulose, are derivatives of naturally occurring organic materials.

'Plasticity' is generally associated with substances of high molecular weight. These macromolecules may consist either of long chains or of mesh-like structures. The chemist can now synthesize macromolecules (or modify naturally occurring macromolecules) to give products possessing chemical and physical properties which to some extent can be predicted. He is rapidly becoming expert, as someone has aptly put it, at 'tailoring the molecule.' He does all this using only a few basic raw materials: coal, petroleum and cellulose.

It has been found, for example, that plastic substances of non-polar or hydrocarbon character are excellent high-frequency dielectrics. Synthetic resins consisting of macromolecules derived

FIGURE 2 – *Injection-moulded polystyrene: used in high-frequency coil formers.*

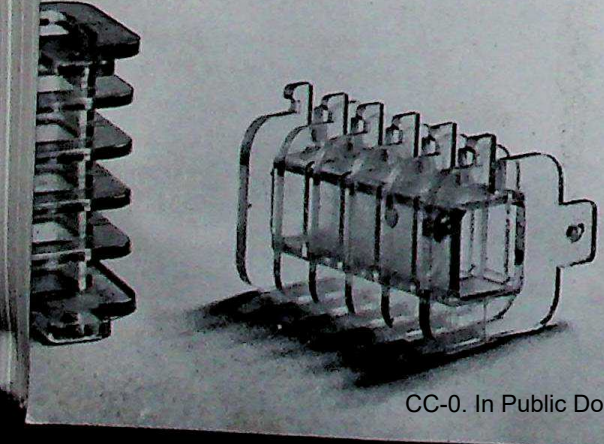
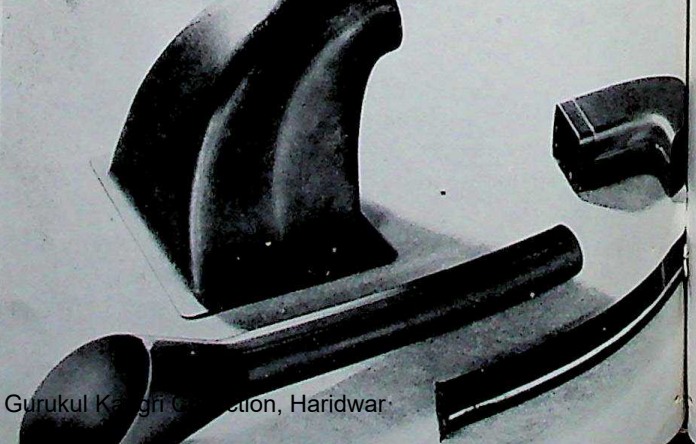


FIGURE 3 – *Ducts of cellulose acetate used in aircraft.*



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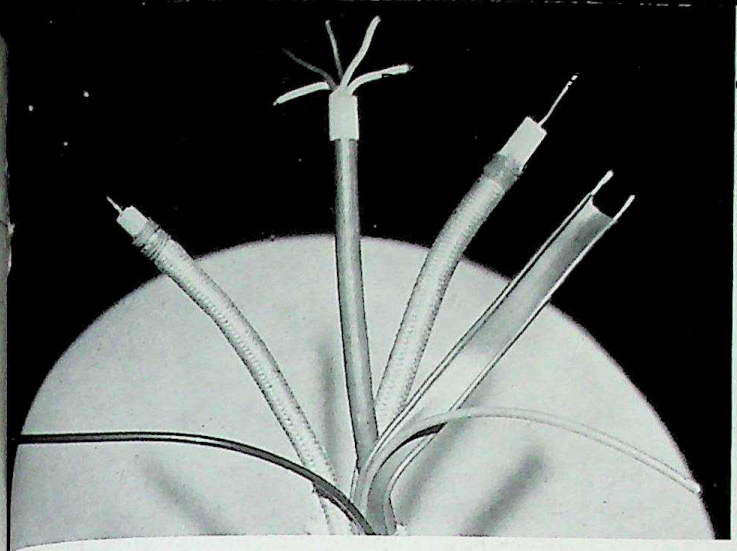


FIGURE 4 – *Electric cables insulated with extruded polyvinyl chloride.*

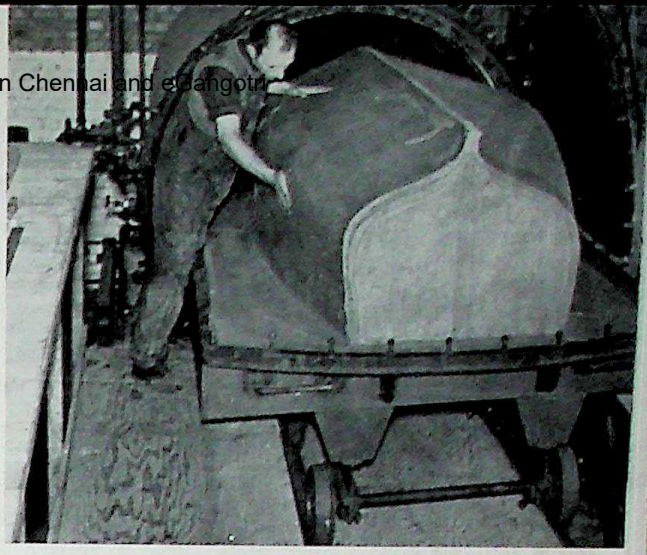


FIGURE 5 – *Boat moulded from resin-bonded plywood in course of manufacture.*

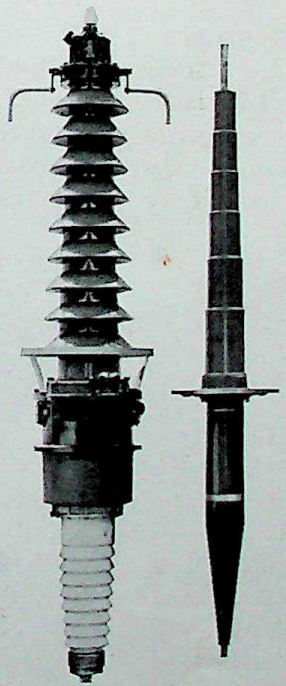
from hydrocarbons such as styrene, isobutylene, and ethylene combine the desirable dielectric properties with fair mechanical strength. Another interesting and still more recent development has been the synthesis of resins which, when in a plastic condition, can be drawn into valuable fibres for textile uses or into filaments for use as bristles, gut, etc. Natural fibres consist of cellulose or protein macromolecules oriented in the direction of the fibre axis (see this Journal, Vol. I, No. 2, pp. 70–73). The chains of synthetic linear macromolecules are generally arranged in random fashion, and only those plastics the molecules of which can be similarly oriented by stretching while in the plastic state have proved suitable for the production of fibres. Notable successful examples are nylon, which is an idealized protein, and vinyon, which possesses excellent chemical resistance. In a similar manner, many macromolecules have been synthesized which have rubber-like properties.

The development of glass-clear synthetic resins has been largely empirical, but the value of the products, such as polymerized methylmethacrylate, is now well established. Transparency, toughness, and ease of working ensure a permanent future for this type of material.

The macromolecules hitherto used as industrial plastics have a 'backbone' of linked carbon atoms, but resins (polymerized methyl silicones) have recently been developed in which the 'backbone' consists of silicon and oxygen atoms. These have been suggested for use as electrical insulation at high temperatures, since their resistance to heat is greater than that of the carbon-linked polymers[1].

While the shaping of plastics into useful articles usually depends basically on the application of heat, the exact technique followed may vary considerably in different cases, and is influenced by the nature of the resin, the character of the article to be fabricated, and the presence and nature of any reinforcing or filling ingredients with which the resin may be compounded.

FIGURE 6 – 132 *kV. oil circuit - breaker bushing, showing alongside the resin-insulated condenser bushing without the porcelain and current transformer housing.*



The simplest way of moulding plastics is by shaping sheets of material, while softened by heat, over wooden forms. Cellulose acetate and polymethylmethacrylate are fabricated into cockpit covers, windows, etc., for aircraft by this process. A method particularly suited to producing rods, tubes and similar simple shapes in continuous lengths is to extrude the heated plastic by a worm through a die. An example of this process, growing in importance, is the production of sheathing from

[1]For further information on these materials, see Rochow and Gilliam, *J. Amer. Chem. Soc.*, 1941, **63**, 798; Brit. Pat. No. 542655, 21st January, 1942.

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FIGURE 7 – *Nylon-bristled brush for furnishing colour to a printing roll.*

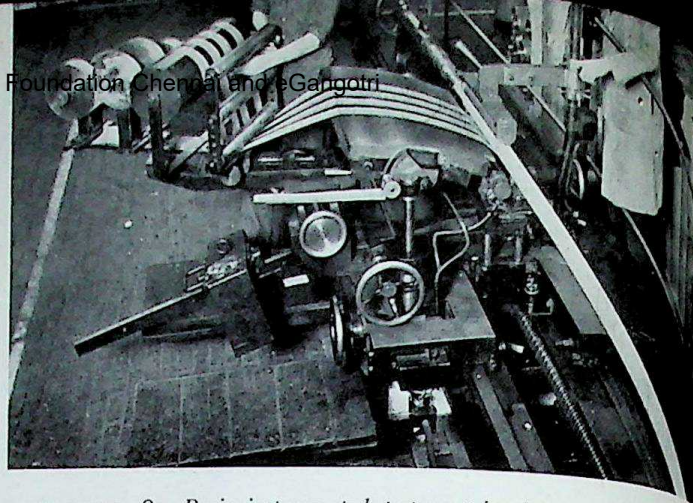

FIGURE 8 – *Resin-impregnated paper strips being wound in spiral fashion on to a conductor for insulation.*

plasticized polyvinyl chloride for use in insulating electric cables.

A major development of the plastics industry has been the compression moulding process, in which a moulding powder, compounded from wood-flour, wood-pulp, cotton-flock, chopped fabric, etc., and a synthetic resin, is heated, under considerable pressure, in an appropriate mould. Another method of fabrication is the injection-moulding process, in which material in the plastic state is forced through a heated die into a chilled mould. Cellulose acetate, polystyrene, etc., are often shaped in this way, the process being capable of rapid output, as three to four complete cycles a minute can be performed.

The mechanical strength of synthetic resins themselves, even when compounded with materials such as those already mentioned, although adequate for many applications, is not as high as theoretical considerations indicate to be possible. From such considerations alone, plastics should be very strong, but, in practice, they are relatively weak. Now, the tensile strength of unfilled plastic material can be calculated theoretically on the assumption that, in rupture, either (*a*) the exchange forces between neighbouring atoms are overcome, or (*b*) the breaking stress is such that the long molecules are drawn apart in spite of the VAN DER WAALS' forces expressing the electrostatic attraction between them. In the case of the familiar phenol - formaldehyde, the ratio of the theoretical tensile strength to the practical value is found to be 500 on assumption (*a*) and 5 on assumption (*b*).

Much, of course, may be done by suitable reinforcement. Mineral reinforcements, such as asbestos fibres, are valuable as conferring resistance to heat and chemical attack, while abrasive metallic powders, slate dust, etc., may be useful to satisfy special requirements. To get a substantial degree of increased mechanical strength, however, strong fibrous reinforcements are needed. Such reinforcements are usually in the form of

FIGURE 9 – *Fabric-reinforced moulded components used in aircraft.*

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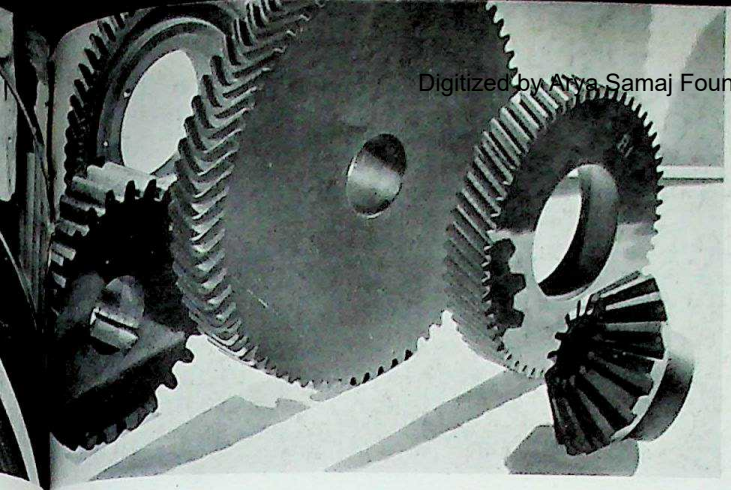

FIGURE 10

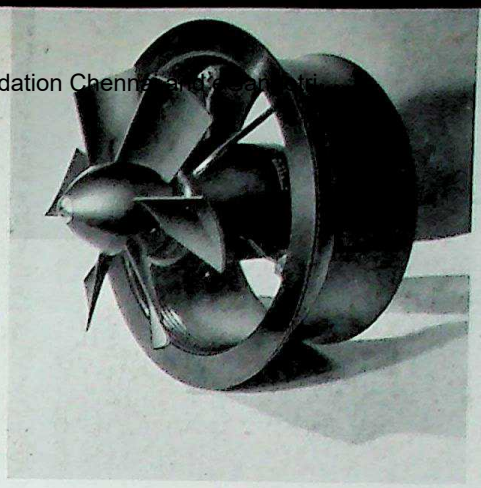

FIGURE 11

FIGURE

paper or fabric, the layers of which, impregnated with the resins in solution, are bonded together under heat and pressure. The resulting laminated sheet can be shaped to a certain extent, and is particularly useful as stock material from which bearings and silent gear wheels can be made. Impregnated paper may also be wound on to a heated mandrel to give tubes used for electrical purposes, such as transformer bushings.

Finally, plastics are now being used on an increasing scale in the manufacture of moulded plywood. The veneers are bonded with synthetic resin glues by a process which is a development of normal plywood and plastic moulding techniques. The advantages of using these synthetic cements are that the laminated products are strong and waterproof, and that parting of the plies does not occur in damp conditions.

FIGURE 10 – *Gear wheels machined from fabric-base laminated sheet.*

FIGURE 11 – *Air extractor housing and impeller moulded from filled phenolic resin and resistant to corrosive fumes.*

FIGURE 12 – *Reaction vessel made from asbestos-reinforced phenol-formaldehyde and possessing great resistance to chemical attack.*

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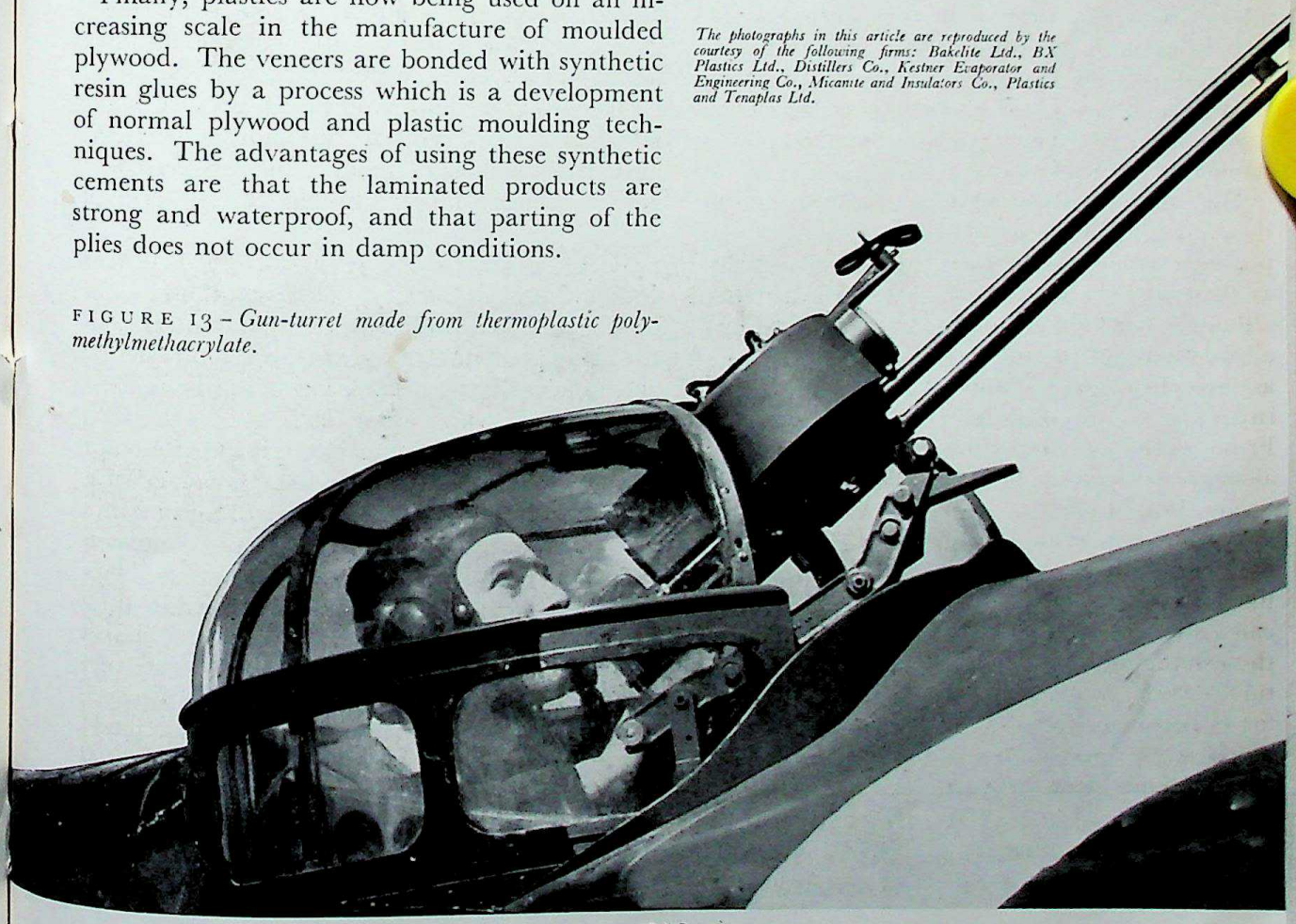
FIGURE 13 – *Gun-turret made from thermoplastic polymethylmethacrylate.*



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Disease-resistant plants

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F. T. BROOKS

Many valuable crop plants are liable to serious diseases. Fighting these diseases by chemical methods is generally either impossible or too expensive. Botanists and plant breeders have therefore adopted an alternative course, and by systematic hybridization have produced, of many important plants, varieties which are highly resistant to disease. Notable results have been attained with wheat, potatoes and tomatoes.

Disease takes as heavy a toll of cultivated plants as it does of human beings. Chemists have played a prominent part in controlling plant diseases, even though, as yet, chemotherapy in plants has no striking successes to its credit as in the cure of certain human maladies. The lifeless sap of plants and its movements in the tissues are quite unlike the living blood-stream of animals; consequently, the possibility of applying the methods of chemotherapy successfully in plants is still remote, although some slight progress has been made by injecting diseased woody tissues in trees with substances toxic to the invading fungus but harmless to the plant. In the domain of plant pathology the outstanding successes of chemists concern the prevention of foliage and fruit diseases by spraying or dusting the plants with fungicides, and the elimination of seed-borne diseases by dusting the seed with fungicidal substances, especially organic mercury compounds. There are, however, large groups of plant diseases which cannot at present be controlled by chemical means, either through inherent difficulty or owing to excessive cost. Many diseases caused by rust fungi are in this category and so are several diseases contracted through the soil. In North America, wheat rust has been experimentally controlled by frequent dustings with sulphur from low-flying aeroplanes, but the cost is excessive. Similarly, although disease germs in the soil of a glasshouse can be destroyed by heat or chemical means, there is no known method of eliminating parasitic soil fungi over large areas of soil without extravagant cost or rendering the soil unsuitable for plant growth.

Fortunately, Nature herself provides the means in many instances of controlling or appreciably alleviating these difficult plant diseases. Practically all crop plants which have been in cultivation for long ages exist in the form of innumerable varieties which differ remarkably in their reaction to specific diseases, some being very susceptible while others are resistant or even immune to attack. It may be asked why varieties susceptible to disease continue to be grown. The reason is that many susceptible varieties give a heavy yield of high-quality produce, especially in seasons when disease is not unduly prevalent, while many resistant varieties crop poorly or suffer from some other serious commercial defect. It is obvious that if, by hybridization, resistance to disease could be combined with the valuable attributes of the susceptible variety, definite progress would be made. Some of the earlier plant hybridists had this in mind towards the beginning of the nineteenth century—for example T. A. KNIGHT in Britain—but little advance was made because at that time there was no clue to the mode of transmission of hereditary characters in plants and animals. Another notable pioneer in this respect was WILLIAM J. FARRER, who from 1886 onwards deliberately set about the breeding of wheats in Australia to resist rust attack. At that time rust laid a heavy toll on the yield of Australian wheat year after year. Farrer achieved much success even before 1900, which, as will be seen, was a critical year in the history of plant genetics. The varieties of wheat now grown in Australia are chiefly derivatives of those which Farrer produced, and they are much more resistant to rust than those grown before he began his work. Between 1890 and 1920 wheat production in Australia increased from 27 million to 144 million bushels, and this was largely due to the introduction of varieties created by Farrer.

In 1900 an event happened which has had a profound and even revolutionary influence on plant-breeding methods ever since. In that year was rediscovered a most important paper on the laws of heredity in plants by GREGOR MENDEL, abbot of the monastery at Brünn, Czechoslovakia,

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which had been published in a local obscure periodical in 1866. Three European botanists independently called attention to the vital importance of Mendel's paper and announced that they had confirmed Mendel's results. How such a paper came to be overlooked for so long is a mystery, but even CHARLES DARWIN, who died in 1882, was unaware of Mendel's discovery. Mendel experimented with different races of garden peas (*Pisum sativum*) and showed that such characters as stature of plant, colour and shape of seeds, and colour of flowers were transmitted according to definite laws in the progeny of the hybrids established between races differing in such characters. Furthermore, it was clear that hybrids established between races differing in two characters gave some progeny showing different combinations of characters from those in the original parents. Mendel's discovery is the greatest ever known in plant breeding, and investigators in different countries soon showed it to be of general application. Here, then, at last was a clue which would enable plant breeders deliberately to synthesize new varieties of crop plants. Plant breeding was no longer a hazardous art; to a considerable extent it had become an exact science. To return to wheat: it was now possible to envisage the creation of new varieties which, while retaining the valuable commercial qualities of the old varieties, would also be resistant to such diseases as rust.

Sir Rowland Biffen.
From the painting by Kenneth Green.

In 1899 R. H. BIFFEN (now SIR ROWLAND BIFFEN) was appointed botanist to the newly founded Department of Agriculture in Cambridge University, and in this post he set himself the task of trying to improve the productivity and quality of English wheat. With the rediscovery of Mendel's paper in 1900 he was provided with a potent instrument for the prosecution of his investigations. One of the first matters to engage his attention was an endeavour to breed wheats less susceptible to yellow rust (caused by the fungus *Puccinia glumarum*) than those commonly cultivated at the time. In England, yellow rust is the most serious rust of wheat, but in certain other countries stem rust (*Puccinia graminis*) is more important. It was not then known whether susceptibility and resistance to yellow rust were transmitted hereditarily in accordance with Mendel's law. Biffen therefore crossed a very resistant wheat (American Club) with a very susceptible one (Michigan Bronze), and showed that when the hybrid was self-pollinated segregation of these characters occurred in the next generation in accordance with Mendelian expectation. The full results were published in the *Journal of Agricultural Science* in 1907. Thus for the first time it was demonstrated that susceptibility and resistance to a specific disease are characters which are transmitted hereditarily in a perfectly definite manner, like certain other plant characters. The way was now open for plant breeders throughout the world to attempt hopefully to create new varieties of crop plants resistant to certain parasitic diseases which were difficult or impossible to control by the usual means. Biffen applied the information he had newly acquired to build up a variety of wheat which would retain the valuable qualities of the old varieties and be at the same time resistant to yellow rust. He crossed together Square Head's Master—a popular heavy-cropping variety but susceptible to yellow rust—with an exotic variety, Ghurka, which though cropping poorly in England was very resistant to this rust. Some of the segregates from this process of hybridization were found to possess in greater or less degree the valuable qualities of Square Head's Master together with resistance to yellow rust. These new types were tested for some years, and the best one, Little Joss, was put on the market and is now one of the most extensively grown wheats in this country. Because of its resistance to yellow rust it crops even more heavily than Square Head's Master. In the great wheat-producing countries of the United States, Canada, Australia, and India, stem rust (*Puccinia graminis*) is the chief menace to production. Departments of Agriculture and state-aided institutions have devoted much energy during the last forty years to the creation of wheats resistant to this rust and otherwise suitable to local conditions. Various complications have arisen, notably because this

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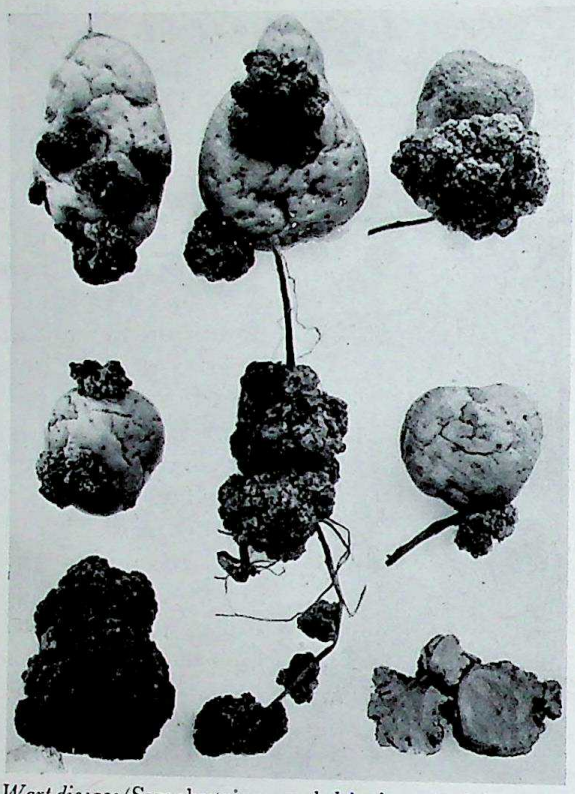
fungus exists in the form of many physiologically distinct races which differ in their incidence from year to year. It is useless, therefore, to breed a wheat resistant to only one of these races: what is required is a variety resistant to all the common races liable to occur in a particular area. In the great wheat belt of North America two varieties have been produced in recent years which fulfil this requirement, viz. Thatcher, made at the University of Minnesota, and Renown, created by the Canadian Department of Agriculture at Winnipeg. These varieties are tending to replace the well-known Marquis wheat because of their greater resistance to rust. In Australia varieties are now available even more rust-resistant than those produced by Farrer.



Wart disease (Synchytrium endobioticum) *of the potato.*

The problem of making disease-resistant crop plants is one which every important agricultural country must face. Each country must work out its own salvation. To be commercially successful each new variety must be adapted to local conditions, and, as already pointed out, the deleterious fungi or their races may differ from country to country. This is now universally recognized and the agricultural authorities of all countries are taking steps to produce varieties suitable to their own countries. Plant breeders, and plant pathologists in association with them, have a full programme for many years to come. In many instances it is important to produce varieties resistant to more than one disease, and such syntheses are necessarily slow. A variety bred to resist one disease may be very susceptible to another, so that only gradually can crop plants be built up which are resistant to several serious diseases.

Potatoes are a crop afflicted by a number of important diseases, not one of which can be overlooked by the plant breeder seeking improved varieties. To mention the most important troubles: wart disease (*Synchytrium endobioticum*), contracted from the soil, transforms the tubers into inedible monstrous growths (*see below*); blight (*Phytophthora infestans*) destroys the haulm, reduces the crop and rots the tubers; and viruses may so impede growth as to render the crop negligible. Admittedly, blight can be controlled by spraying the haulm with copper fungicides, but the plant breeder visualizes the eventual production of varieties immune to wart, resistant to blight, and uninjured by viruses. Inspectors of the English Ministry of Agriculture were the first to discover that some varieties are immune to wart, and in recent years new varieties have invariably been tested for their reaction to this disease before being grown commercially. The varieties of potatoes commonly grown in Britain at present are all more or less susceptible to blight, and progress towards the achievement of resistant types is slow, partly because of the extremely hybrid nature of present domestic stocks. SALAMAN, formerly of the Potato Virus Research Station, Cambridge, and REDDICK, in the United States, have, however, made some advance in this direction by hybridizing certain varieties with a Mexican species of *Solanum* which is immune to blight. In South America—the home of our domestic potato (*Solanum tuberosum*)—and in Mexico there are many varieties of potato not in European cultivation, and several closely related wild species of *Solanum;* these constitute a great reservoir of genetical material for use by plant breeders in the creation of new varieties. In recent years the U.S.S.R., the U.S.A., Sweden, Germany, and the Imperial Agricultural Bureaux of the British Empire have sent expeditions to Mexico and South America to collect this valuable material. The British expedition returned in 1939, and the collections are now being investigated by the Imperial Bureau of Plant Genetics in association with the Plant Breeding Institute at Cambridge. Perhaps with the new material now available the perfect potato will be produced: free from disease, of good quality and

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Upper part of silvered Victoria plum tree, one branch of which is dead and bears fructifications of Stereum purpureum.

cropping capacity, and uninjured by moderate frost.

There is hardly a herbaceous crop plant grown in temperate countries which has not been improved in recent years as regards disease-resistance, but space permits mention of only one more example. The interests of growers of crops under glass, e.g. tomatoes, are also being watched by plant breeders. Here leaf mould (*Cladosporium fulvum*) is one of the chief culprits. Canadian workers have hybridized the tomato with the small currant tomato which is immune to attack, and have produced the variety Vetomold, which is both immune and highly productive. Preliminary trials with Vetomold in this country have been very successful.

The production of disease-resistant types of arborescent plants is inevitably slow, and is a formidable undertaking even for institutions which have facilities for experimenting over long periods of years. How valuable it would be in this country if we had a variety of plum with all the good qualities of the variety Victoria and at the same time resistant to silver-leaf disease caused by the fungus *Stereum purpureum!* This fungus invades the woody tissues of the tree through wounds and speedily causes death, fructifying on the dead branches (*column* 1). Attention to plant hygiene minimizes the risk of invasion, but a similar variety resistant to this disease is greatly needed by fruit-growers.

With tropical crops much attention has been and is being paid to the breeding of resistant types. Losses from epidemic disease are likely to be particularly severe under tropical conditions. One of the most notable achievements in the tropics is the production by the Dutch in Java of varieties of sugar-cane uninjured by certain virus diseases, by means of which the output of sugar has been greatly increased. The banana industry in Jamaica and certain parts of Central America is now threatened by Panama disease, caused by a fungus contracted from the soil. There is no known means of control apart from the breeding of a resistant variety. The tropics of the Old World have been ransacked for banana varieties in the hope that some of them would prove resistant to the disease. These were first sent to the Royal Botanic Gardens, Kew, and kept in quarantine there to ensure that they were not afflicted by other serious diseases before being sent to the West Indies. Some of these varieties have proved to be resistant to Panama disease, and geneticists in Jamaica and Trinidad are now using this material for hybridization. It is not, however, sufficient to produce a banana which fruits well and resists the disease; it must also have the valuable qualities of easy and safe transport by sea over long distances possessed by the present Gros Michel variety.

Another disease which is causing concern in the West Indies and contiguous lands is witches' broom of cacao (cocoa), again caused by a parasitic fungus, and again difficult if not impossible to control by the usual means. A few years ago a British expedition was sent into the upper reaches of the rivers Amazon and Orinoco to collect wild varieties of cacao resistant or immune to this disease. The material so collected is now being utilized by plant breeders in Trinidad.

Even the humble flower gardener, as well as the cultivator of broad acres, wants disease-resistant varieties. For rust-resistant antirrhinums he will probably not have long to wait, since investigations in California and at the Royal Horticultural Society's gardens at Wisley, Surrey, have shown that good sturdy types can be produced.

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The propagation of sound in the atmosphere

E. G. RICHARDSON

The transmission of sound in the air shows many peculiarities, frequently of a very surprising kind. Explosions and gunfire are often inaudible in regions comparatively close at hand, while distinctly audible at greater distances. Echoes of a foghorn may sometimes be heard for as long as 15 seconds after the original sound has been cut off. In this article, Dr Richardson provides an interesting account of recent investigations carried out on the subject by British and other workers.

Much work has been done in the last two decades on the transmission of sound to great distances from a powerful source, such as that produced by the firing of a heavy calibre cannon or by the blowing up of dumps of unwanted explosives after the last war. It was observed between 1915 and 1918 that the sound of gunfire from the Western Front was audible in places in the vicinity of London, whereas at intervening places in Kent nothing was heard, even in the presence of a favourable wind gradient. The existence of such 'zones of silence' was confirmed when at prearranged times and places explosions were staged *ad hoc*. In this work, the occurrence of a region where the sound is inaudible in spite of the fact that it is distinctly audible at a greater distance from the source was confirmed. An inner zone of audibility, in which the sound-rays travel directly over the surface of the earth, to be frittered away by expansion of the wave-front and in friction over broken ground, trees, etc., is found to surround the source with an irregular area. Follows the silent zone, in which, although no sound is heard, there are indications of an inaudible pulse of low frequency. Outside this there is the abnormal zone, where the sound reappears with renewed intensity, but apparently taking an exceptionally long time to arrive.

This last factor naturally leads one to suppose that these sound-waves have travelled into the upper regions of the atmosphere and down again, the abnormal intensity on the inner fringe of this zone being ascribed to the convergence of rays which have traversed slightly different paths to this point, and to the absence of friction, other than air damping, in the stratosphere. Since the temperature under normal conditions is known to decrease in the first 17 km. above the earth's surface and, with it, the velocity of sound, we must assume that, in the absence of refraction caused by wind gradients, paths of sound-rays are concave, viewed from above, in these regions. The information on temperature is obtained from pilot balloons —small balloons carrying a cage of instruments to read temperature, pressure, and humidity at the altitude at which the balloon is set to burst, the cage then falling safely to earth under control of a parachute which opens on release from the lift of the balloon. At the present ceiling of pilot balloons, however, there are indications that the temperature is ceasing to fall, and meteorologists postulate a temperature inversion at this height and assume that above this level the stratosphere is so heated by the sun's radiation that warmer regions are rapidly entered. It is evident indeed that something must happen to the sound-waves in this region to turn them back to earth—something, that is, to give a convex track (seen from above) to rays in the stratosphere. Short of a sudden reflection at a barrier formed by a definite discontinuity in atmospheric properties, this implies a region in which the velocity is continually increasing upwards, whereas below in the troposphere the velocity decreases with height.

From the direction at which the sound in the abnormal zone is noted to return to earth, it has been estimated that rays reaching the outer edge of this zone (usually about 200 km. from the source) had an original inclination of 40° to the horizon. It is, then, a matter of putting forward hypotheses for the velocity of sound above 17 km. and testing these against the known time of propagation of the sound from the source within the prescribed surface distance (180 to 300 km.). Such hypotheses must make the summit velocity high, otherwise such rays would not be turned back. The simplest hypothesis seems to be to suppose that above the inversion level the velocity

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of sound rises at such a rate that at between 30 and 40 km. the surface velocity is reached again and subsequently exceeded. This gives the ray reaching the outer edge of the abnormal zone a summit level of 70 km. Those with an initial trajectory angle greater than 40° are 'lost,' unless reflected by acoustic clouds. The vertical projections of such sound-rays are shown in figure 1, and the collected results of one such explosion (under the aegis of the International Commission for the Investigation of the Upper Atmosphere) are shown in figure 2, viz. at Kummendorf in December 1925 (after DUCKERT [1]). The zone where the sound was heard at normal velocity is shown in the centre. The abnormal zone of apparently low velocity is indicated by horizontal hachuring. It may be noted that it is more definite to the east of the source in summer and to the west in winter (a general feature on which surface winds have little influence). When one writes 'apparently low velocity' one means, of course, that it is low reckoned in terms of the surface distance. Actually, as we have noted above, it has travelled at abnormally high velocity over the greater part of its trajectory. There are indications, after further silent gaps, of sectors of two more audibility zones (marked in vertical hachures) to the west. These are ascribed to 'ricochets' of the rays at the surface when they come down on their first trajectories, so that the process of penetration to the stratosphere and back is repeated with diminishing intensity. The approximate equality of the lengths of such jumps can be gauged from the separation of the zones on figure 2.

Measurements have also been made in England by WHIPPLE [8], using gunfire as source, with sensitive microphones set up at different stations about 70–100 miles away. These confirmed the seasonal variation noted in the explosion trials; in this series reception was better in the western and north-western directions from the origin (Woolwich or Shoeburyness in the Thames estuary) from May to August, but at the north-eastern station (in Norfolk) in the winter. It is possible that seasonal winds in the upper atmosphere may account for these variations.

We now turn to the hypotheses which have been put forward to explain the track of the sound-rays in the stratosphere, bearing in mind that no hypothesis is tenable which does not give velocities of sound increasing with height.

On the three physical constants appearing in the Laplacian expression for this velocity, pressure

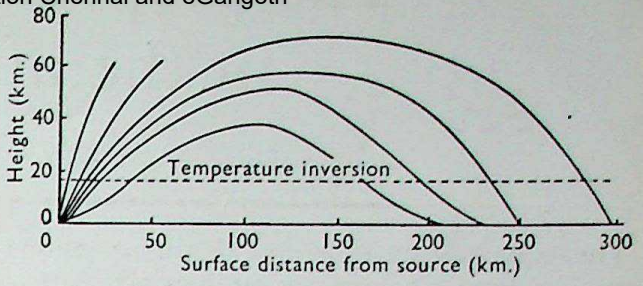

FIGURE 1

per se can have no effect. There remain temperature and composition of the atmosphere as variables. For an increase in velocity, temperature must rise, or the atmosphere must become richer in lighter molecules than it is in the troposphere, or both changes must occur.

Near the surface of the earth, as is well known, the atmosphere consists mainly of the diatomic molecules of oxygen and nitrogen with small admixtures of the rare gases, argon, helium, neon, etc. The latter are monatomic. The question of the number of atoms in the molecule is important, because the ratio of specific heats at constant pressure and at constant volume (which comes into the expression for the velocity of sound) depends on this. For most monatomic

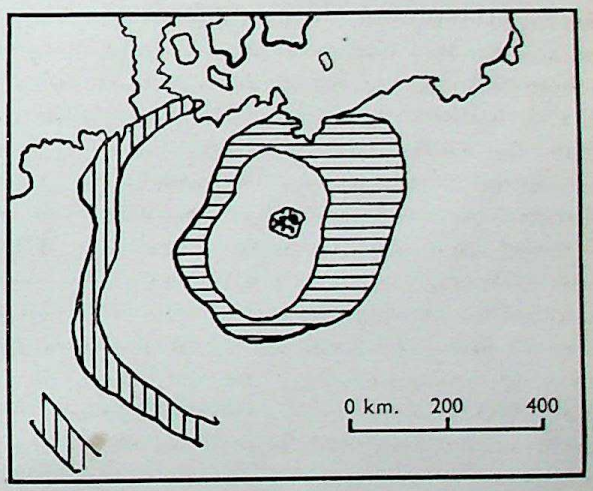

FIGURE 2

gases it is 1·66, for diatomic 1·41, and for triatomic 1·3. Apart from density changes, therefore, the effect of dissociation of the air completely into atoms—if that were probable—would raise the velocity of sound by a mere 8 per cent. It is in fact known that above 25 km. atomic oxygen becomes more and more prevalent, but this condition alone is scarcely likely to produce the increase we are looking for.

Some other information is obtainable from the

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spectrum of the aurorae, electrical phenomena known to have their origin in the upper regions of the atmosphere and whose light might be regarded as characteristic of these regions; though this light has, of course, to pass through the troposphere before reaching the spectrometers here. It appears that the helium content of the atmosphere remains constant from the ground up to 20 km., but above that increases slightly relative to oxygen. The existence of hydrogen in the stratosphere has not been confirmed. In any case, we should require a high proportion of this gas to give the required rise in velocity of sound, if the latter is to be ascribed solely to composition. We are therefore led to adopt the rising temperature hypothesis. If, indeed, the effect on velocity is entirely to be ascribed to temperature, we must postulate that, from the inversion at 17 km., the temperature reaches its surface value again at 40 km., and by 50 km. has passed 70° C. Such an idea is quite contrary to the older meteorological theories, and though it is by now generally accepted, little is known of the mechanism by which these layers are warmed. They are, of course, considerably rarefied, so that the sun's radiation is able to reach the gaseous molecules without much absorption by other molecules lying further still on the confines of the stratosphere, whereas the heat which reaches us has been so filtered or reflected by gases and water vapour. This suggestion is rather spoilt by sound-propagation experiments carried out from Russian arctic stations during polar nights. Similar anomalies in the zones were observed to those which persisted in the daytime. It is, of course, possible to retain the solar radiation theory and to postulate that the polar cap stratosphere remained warmed during the night by convection currents or winds from lower latitudes.

Experimental study of atmospheric influences in surface propagation was made in 1870 by TYNDALL for the Trinity House Brethren, who have charge of the navigation lights and sirens round the British coast. The sirens at the South Foreland were chosen for the experiments. He reached the result, surprising at that time, that an overall fog accompanied a favourable perception of the signals. This was not due to the atmospheric moisture itself, but to the fact that fog is an indicator of stable and homogeneous atmospheric conditions. It is when the atmosphere is 'patchy,' i.e. having a diversity of density at different points, with unequal temperature and humidity distribution, that fluctuations occur in the audibility of the sirens, both in time and in space.

Sometimes these patches, in the form of acoustic clouds, caused continuing echoes of the blast lasting as much as 15 seconds after it had been turned off. Owing to the presence of such reflecting patches in the atmosphere a siren giving a continuous note of short duration is sometimes heard better, and sometimes worse, than the crack of a gun giving a short impulse.

MAJOR TUCKER [7] has explored the sound field round the North Goodwin and Casquet sirens. During a typical summer day the intensity of the sound picked up varied irregularly in a 30 to 1 ratio over a period of a few minutes. A favourable temperature gradient for the propagation of sound was experienced when air had passed over a land surface at high temperature and subsequently had its lower strata cooled by passage over the sea in the neighbourhood of the source [6]. In these cases, again, an overall reduction in humidity was generally accompanied by a reduction in audibility.

When the atmosphere is not homogeneous in density at any level the variation is, of course, usually caused by clouds or fog banks. Apart from the grosser type of reflection and refraction caused by obstacles such as these, which are huge compared to the wave-length of all sounds, there is another source of scattering of sound which parallels the same phenomenon in light—that scattering which occurs when light passes through a smoke or other suspension of particles, of the same order of size as the wave-length of the light. Although even the largest raindrops cannot approach the wave-length of bass notes, the lengths of high-frequency sound-waves near the upper limit of the treble are to be reckoned in millimetres. The extent to which obstacles of this kind upset the normal passage of high-frequency or supersonic waves has been exhibited in some recent research [4] in which such a beam has been passed through artificial smoke suspensions of magnesium oxide and lycoperdon spores. (The spores of this fungus are nearly spherical and of uniform size.) The results show that there is a considerable absorption of sound energy as the frequency increases. This is borne out in practice. It is well known that on a misty day, or on one accompanied by rain showers, the 'speckled' character of the atmosphere results in considerable attenuation of high-frequency sounds, while those of lower frequency are left unaffected.

The latter are in fact more likely to be

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disturbed in propagation on occasions the distorting elements in the sound-field are the eddies set up by turbulence. These can well extend to several feet in diameter and are capable, in spite of their intangibility, of upsetting the propagation of quite long waves, even in a homogeneous atmosphere. KNUDSEN [3] discovered that the rate of decay of reverberation in a room, after a loud-speaker sound-source had been turned off, varied considerably with humidity. The classical absorption (due to friction and heat-conduction)

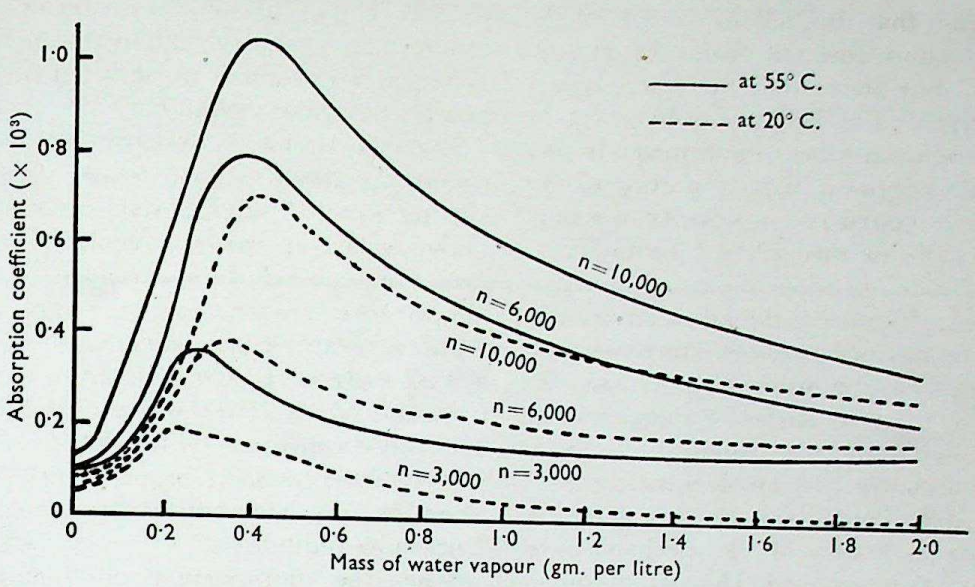

FIGURE 3

though the actual degradation of energy is not so certain as with solid or liquid obstacles and high-frequency sounds.

Quite recently, EAGLESON [2] has carried out measurements of the absorption of sound in the open air at Bloomington, Indiana, over short distances (200 yards) at audible frequencies, which show well how the 'classical' idea of absorption is set aside when banks of fog, clouds, and rain are about. Whereas theory and practice could be brought to agree within the somewhat surprising figure of 1 per cent. under good homogeneous atmospheric conditions, patchiness of the atmosphere produced vagaries in the readings of the instruments amounting to 10 per cent. of normal after allowing for the effect of average humidity on the anticipated absorption.

There is yet another cause of selective absorption which is quite small in comparison. At a given temperature, the absorption coefficient reaches a maximum at a certain value of the humidity (cf. figure 3). Put another way: at constant humidity, the coefficient of absorption increases markedly with frequency, the effect being more important at large water-vapour pressures. The effect, too, has been pursued into the supersonic range of frequencies [5]. That this is a form of molecular absorption is not in dispute, though the precise way in which a comparatively small number of water molecules can confer rigidity on the oxygen and nitrogen molecules so that they damp the vibrations passed through them is not yet properly understood. At any rate, the experiments add point to the noticeable attenuation of high-frequency waves in Nature, upon which we have already remarked.

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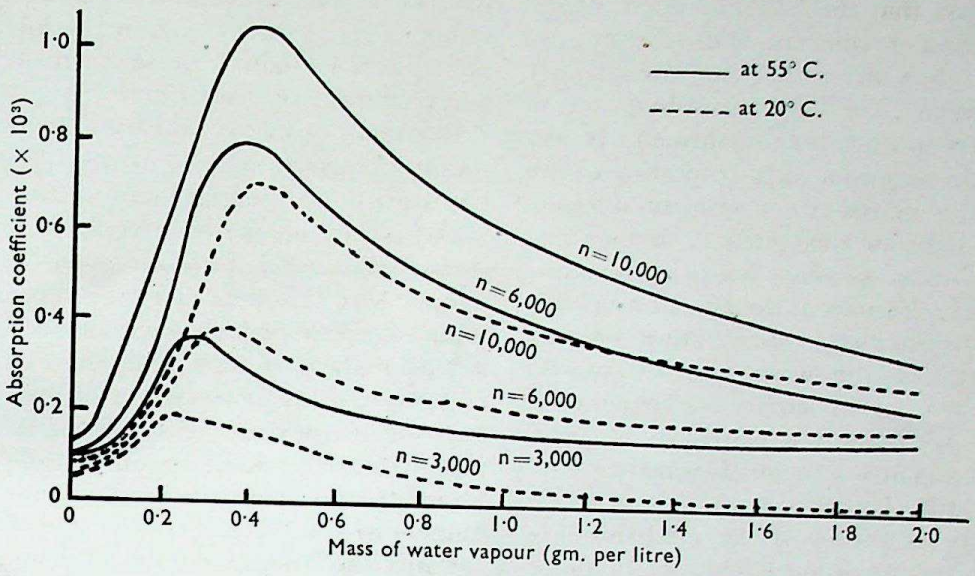

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Progress in bacterial chemotherapy

L. P. GARROD

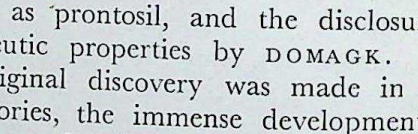
In the short space of seven years, progress in the chemotherapy of microbic infection has effected dramatic changes in medical practice. Pneumonia, cerebro-spinal fever, puerperal fever, and 'blood-poisoning,' which formerly ranked as intractable scourges, are now amenable to treatment. Professor Garrod describes some of the new drugs responsible for this transformation, and offers a convincing explanation of their mode of action.

In countering the attack of microbic infection, a remedy which will destroy the micro-organism itself will clearly be the most certain in its action. If a drug capable of doing this can reach the affected area in the circulating blood, thus pervading it completely, the therapeutic ideal has been attained. It need scarcely be said that most 'antiseptics' are wholly unsuited for such a purpose: they are far more lethal to man himself than to the micro-organisms which attack him. It is broadly true that the more complex an organism, the more readily is it poisoned, and a substance relatively harmless to the human body but nevertheless lethal to a unicellular micro-organism must have exceptional properties and will not be easy to find.

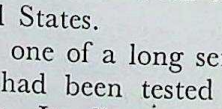
Until recent times a sharp distinction has been drawn in this connection between protozoa and bacteria. The former belong to the animal kingdom, are somewhat more complex in structure and metabolism, and were believed on these grounds to be more susceptible to attack. The efficacy of quinine in malaria and of ipecacuanha in amoebic dysentery has long been practical evidence for this belief. Bacteria, on the other hand, are the most primitive members of the vegetable kingdom. No drug was known which would seriously interfere with their activities within the body, and many microbiologists doubted whether such a substance could exist.

The year 1935 marks the abandonment of this attitude and a discovery the consequences of which have revolutionized the practice of medicine. Although the least inquisitive layman cannot have been unaware that a remarkable advance has taken place, its magnitude and significance seem sometimes not to be fully appreciated even by those more directly concerned: the effective control of formerly dangerous diseases by the mere swallowing of tablets has become a matter of course. The acute infections which respond best to this treatment are those which were often fatal in youth or the prime of life—pneumonia, cerebro-spinal fever, child-bed fever and septic infection of all kinds, whether involving war wounds or other gross injuries, or originating in some more trivial way but leading to a state so often formerly described in inquest reports as 'blood-poisoning.' These last were cases before which medical science stood almost powerless: they are now as amenable to treatment as they were formerly resistant. The origin of these and other developments of bacterial chemotherapy was the synthesis by MIETZSCH and KLARER of the drug known as prontosil, and the disclosure of its therapeutic properties by DOMAGK. Whereas this original discovery was made in German laboratories, the immense developments which have proceeded from it are due in the first place to an observation made in France, and subsequently in the main to work in Great Britain and the United States.

Prontosil was one of a long series of azo compounds which had been tested for therapeutic activity in mice. Its discovery was thus purely empirical, and the nature of its action was unknown. It was first postulated by French workers, the TRÉFOUELS, NITTI and BOVET, and confirmed by FULLER in England, that prontosil



is broken down in the body, liberating its active constituent, *p*-aminobenzene sulphonamide,



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a compound now known almost universally as sulphanilamide, although also unfortunately by a large number of confusing trade names. In spite of German opposition to this belief, it was soon established that prontosil owed its therapeutic activity to this constituent, and sulphanilamide itself, which had advantages in greater solubility and more rapid absorption, came into therapeutic use in place of prontosil.

This further discovery has led to the synthesis of innumerable further compounds based on the sulphanilamide molecule, in the hope of obtaining improved effect or of extending the effective scope of this treatment to other diseases. It is beyond dispute that the greatest single advance on these lines was the introduction in 1938 of 2-*p*-aminobenzenesulphonamido-pyridine for the treatment of pneumonia. This drug, known as sulphapyridine, or 'M. and B. 693,' was synthesized by A. J. EWINS and tested experimentally by L. E. H. WHITBY of the Middlesex Hospital. It filled the most serious gap in the capacity of these drugs to arrest acute and frequently fatal bacterial infections. Most of the varied manifestations of infection by streptococci had been controlled by sulphanilamide, but this drug had little action on the closely related pneumococcus, the principal cause of pneumonia, a disease which the late SIR WILLIAM OSLER, borrowing a phrase from John Bunyan, described as 'Captain of the Men of Death.' The effect of sulphapyridine in most cases of pneumonia is dramatic; the mortality of the disease has fallen from a general average of about 25 per cent. to the region of 5 per cent., and the number of lives saved, although entirely beyond computation, probably exceeds the total to the credit of chemotherapy in all other bacterial infections put together. The evaluation of this treatment in adequately controlled studies on a large scale has been carried out mainly in the United States, whence also has recently come another drug, 2-sulphanilamido-pyrimidine ('sulphadiazine'), now in increasing demand not merely for its efficacy, but because it can be taken in large doses without causing the nausea and depression produced by others. This and other advantages are claimed for sulphamethazine [2-(4′-aminobenzenesulphonylamino) 4 : 6-dimethyl-pyrimidine], a new British product the action of which is now being studied before it is made generally available.

Of wider interest than the conquest of any particular infection has been the problem of how these compounds act. They do not behave like ordinary antiseptics, killing bacteria in the test-tube within a few minutes. Prontosil has in fact no action whatever on bacteria outside the body, and that of sulphanilamide is unimpressive when tested by ordinary methods, consisting only of a capacity for preventing the growth of small numbers of bacteria rather than the ability to destroy many outright. It was therefore natural that some mode of action in the body should have been suspected other than one directly lethal to bacteria: the complexity of the processes both of microbic attack and of bodily defence is such that there are many points at which interference might occur. Apart from several hypotheses of this kind, there have been two extreme schools of belief, one of which has been voiced chiefly in Germany by Domagk [1] himself and others. Their attitude has been one of almost reverent agnosticism, as if the progrees of events in an area of infection in the living body subject to chemotherapy held secrets which our present knowledge cannot hope to master. To call a remedy 'echt Chemotherapeuticum' is for them to elevate it to a plane of impenetrable mystery. The extreme opposite of this belief, which has perhaps been more widely held, I expressed myself [2] as long ago as May 1938 and have maintained since; it is that sulphonamide compounds have no occult or indirect action, but check bacterial growth in the body by some interference with the processes necessary for their multiplication. This in itself is enough to secure their destruction, both because bacteria kept at the temperature of the body must either grow or die, and because acute infections progress only by very rapid bacterial multiplication; if this should cease, the growing strength of the forces of defence will inevitably prevail.

It is now known that this is the true explanation, and we can moreover understand precisely how sulphonamide compounds interfere with bacterial growth. For the history of how this discovery came about, we must go back ten years to the foundation by P. FILDES of a laboratory at the Middlesex Hospital for the study of bacterial metabolism. From the time of PASTEUR to the present day bacteria have been cultivated in media containing meat extracts; Pasteur used 'bouillon nutritif,' and 'broth' is still the name of a medium universally employed. For everyday purposes it is enough that most bacteria will grow in a medium composed of meat extract and peptone, the only object being that they

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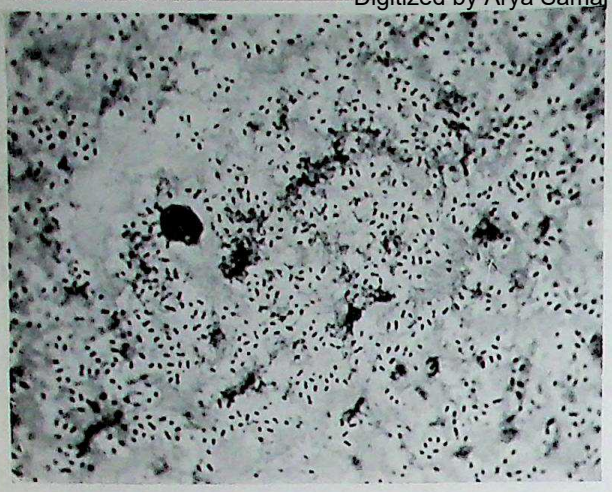

FIGURE 1 (*a*) – *Pneumococci showing normal morphology (elongated deeply stained cocci, chiefly in pairs, and of uniform size).*

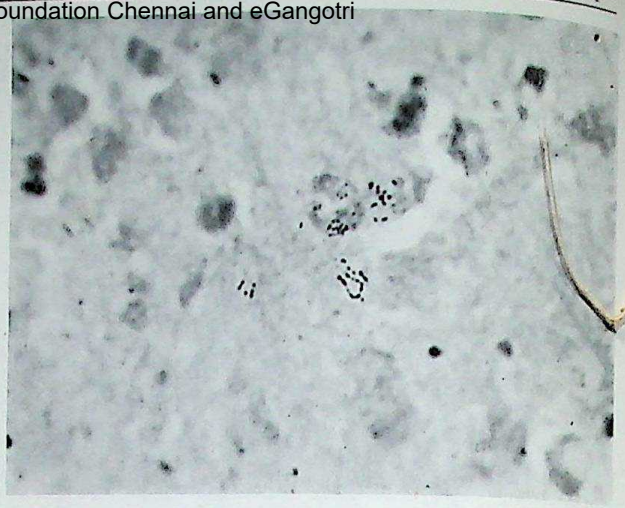

FIGURE 1 (*b*) – *Pneumococci in pus from an abscess unrecognized and untreated for several months. If such a condition remains localized, many of the bacteria degenerate and die, and swollen, shrunken, and poorly staining forms are produced.* (× 475)

should grow. But it would clearly be of great advantage to the fundamental understanding of bacterial activity to know in exact chemical terms what nutritive elements are necessary for their growth. These can only be identified by using media consisting of pure, and preferably synthetic, ingredients, starting in any given case with the simplest possible constitution and making additions until growth is secured. By this method Fildes and his collaborators have amassed extensive and valuable data, and identified various previously unknown 'factors' necessary for the growth of different bacterial species. Having in the course of this work exactly ascertained the growth requirements of streptococci, they were in a unique position to study any effect on the growth of this micro-organism produced by sulphanilamide.

The actual approach to this problem was made in a peculiar way, and owes something to the work of others. J. S. LOCKWOOD [3] of Philadelphia first observed that the restraint of bacterial growth by sulphanilamide *in vitro* is prevented by peptone: this is a constituent of all ordinary culture media, and its presence thus accounts for the unimpressive results of earlier tests. It had long been known that growth-restraint fails when the initial number of bacteria is large, and T. C. STAMP [4] and H. N. GREEN [5] followed this up by showing that a substance can be extracted from streptococci themselves, and from other bacteria, which antagonizes the action of sulphanilamide. Fildes' colleague D. D. WOODS [6] then found that this substance existed in yeast, and since this was a prolific source he was able to fractionate it and test each fraction for its capacity to antagonize the action of sulphanilamide on streptococci in a synthetic medium. By this laborious process he succeeded in identifying the substance concerned as *p*-aminobenzoic acid. Whether obtained from yeast or independently synthesized, it quantitatively neutralizes the action of sulphanilamide on bacteria *in vitro;* it also completely prevents curative action in the infected animal body. These astonishing facts are simply explained. It is now known that *p*-aminobenzoic acid is essential for the nutrition of streptococci and some other bacteria. They can form it themselves, but its further utilization depends on an enzyme reaction which is inhibited by sulphanilamide. An essential stage in the building up of some necessary constituent of the bacterial cell is thus interrupted. In the nutritive environment furnished by the infected mammalian body, the concentration of sulphanilamide which can be produced by ordinary dosage in the blood, and therefore throughout the tissues, achieves this effect. That the death of bacteria under the influence of these drugs is simply death from inanition might well be deduced from the accompanying figures, one illustrating bacteria dying slowly and naturally in a closed abscess cavity probably months old, the other showing the effect on them produced by sulphapyridine in only two days. The degenerative changes are of the same nature in each case.

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FIGURE 2 (*a*) – Streptococcus pyogenes *in pus, showing normal morphology (long curved chains of cocci of uniform size and staining uniformly; the large spherical cells in the background are leucocytes).*

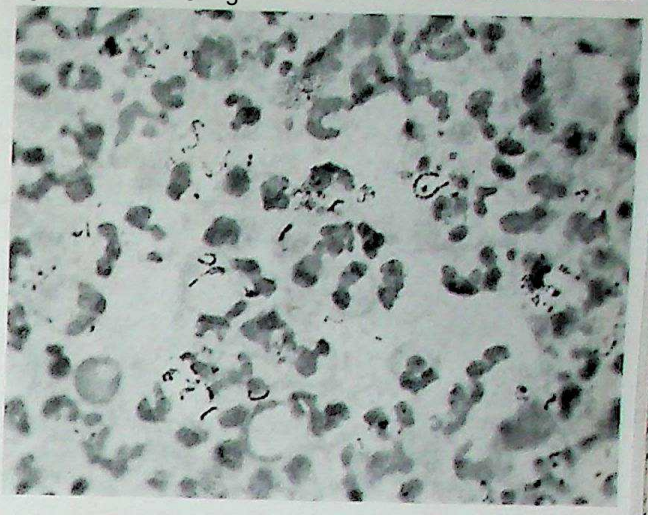

FIGURE 2 (*b*) – *The same micro-organism from an abscess only three days old in a patient treated with sulphapyridine. There is gross irregularity in size and shape, and many of the cocci stain poorly (cf. figure* 1 (*b*)). (× 475)

The profound significance of this discovery needs no emphasis. By laying bare the exact mechanism underlying the greatest therapeutic discovery of modern times it has opened the way to its extension on rational instead of merely empirical lines. It has had a more immediate and practical effect in encouraging and justifying the local application of these drugs in powder form to wounds, a measure which has proved of immense value, particularly in war surgery.

No review of progress in this sphere would be complete without reference to the astonishing observations recently made on the extraction of antiseptic substances from micro-organisms themselves. Whether by chance or as part of the antagonism between species which occurs so often throughout both animal and vegetable kingdoms, certain micro-organisms do produce substances highly inimical to others. Penicillin, a hitherto unidentified substance formed by the mould *Penicillium notatum*, is a powerful antiseptic, and nothing stands in the way of what bids fair to be a valuable use for it in medicine except difficulty of production on an adequate scale. The action of this substance was first observed by A. FLEMING at St Mary's Hospital, London, and has recently been studied by H. W. FLOREY [7] and others at Oxford. Gramicidin is the name given to a substance extracted by DUBOS [8] of New York from an otherwise quite indifferent bacillus isolated from soil; it has properties similar to those of penicillin, and has been reported [9] within the past few months to satisfy a special need in the treatment of wound infection. Here again there are prospects that chemical analysis of the underlying process may place a new form of treatment on a more assured footing. In this field of medical research, in Britain at least, war has been the incentive to rapid progress, and more has been achieved towards the control of infection, particularly of wounds, than might have followed many years of more leisurely study with less motive and material.

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PRACTICAL EXERCISES IN CHEMICAL ENGINEERING

The Applications of Chemical Engineering, *edited by Harry McCormack. Pp. x + 431. Chapman and Hall Limited, London.* 1940. 21*s.*

The title of this book is rather unfortunately chosen and hardly serves to indicate its scope. It is actually a practical laboratory manual in chemical engineering intended to furnish suitable practical exercises for a university course. The work is a co-operative effort of a dozen authors, all engaged in the teaching of chemical engineering at various American universities. It owes its origin largely to the work of two committees of the Society for the Promotion of Engineering Education, which collected together a considerable amount of material on appropriate laboratory instruction.

The book consists of eleven chapters dealing with the most important unit operations of chemical engineering. Although the chapters are by different authors, the general method of treating each operation is the same. After a short exposition of the general theory underlying the unit operation, a number of practical exercises are set out in detail. In connection with each exercise, there are given a statement of its object, a description of the equipment, an outline of the procedure to be followed, and the method to be adopted in reporting the results of the exercise. In all, there are seventy-two exercises included in the book, and a fairly wide choice is thus available to meet local conditions in any particular laboratory. The exercises have all been carefully chosen, satisfactorily tested over a number of years, and designed for use with reasonably simple equipment that should be readily available or easily constructed. Each exercise is designed to bring out basic theoretical principles and to be capable of being carried through in a four-hour laboratory period.

The book is a most valuable contribution to the literature on chemical engineering education and covers a subject which has otherwise been dealt with very sparsely in the published literature. It will certainly be appreciated in this country, where chemical engineering education has not yet developed on the same scale as in the United States, and it can be used without any material adaptation for educational conditions here. In the teaching of any branch of engineering, practical laboratory work is an essential part, as it constitutes the bridge between the abstract scientific principles and their practical applications which the student will later meet with in industry. Careful planning of these practical exercises is most important if the limited time of the student's course is to be utilized to the best advantage. At the same time, it is vitally necessary to avoid exercises of the 'cookery-book' type.

The contributions of the various authors of the book have been well co-ordinated as far as subject-matter is concerned, but less successfully in some points of detail. A marked example is the different methods adopted in various chapters for dealing with references to the literature. There are more printing errors than one expects in a work of this standard, and many minor omissions in the references. No doubt these slight blemishes will be removed in a later edition.

A. J. V. UNDERWOOD

INDUSTRIAL PLASTICS

Plastics in Industry, *by 'Plastes.' Pp. xiii + 248. Chapman and Hall Limited, London. Second edition,* 1942. 15*s. net.*

The main aim of this book is to give those engaged in industry a working knowledge of plastics which will enable them to apply these modern materials of construction to their own everyday problems. That a second edition of the original work was called for nine months after the first is sufficient testimony both to the efficiency with which this aim has been attained and also to the growing interest which technologists are taking in plastics. The first four chapters are devoted to a review of the fundamentals of the industry, beginning with definitions of technical terms involved, a description of the most important thermosetting and thermoplastic materials used, the methods of moulding and fabricating them, and the standard specifications now accepted to control them. Thus the potential user is provided with adequate data which will give him at any rate the preliminary indications as to whether he may expect specific plastics to serve his purpose.

The remainder of the book is devoted to a survey of the part plastics were playing in industrial and domestic life prior to the outbreak of the present war. As far as possible, data have been modernized in the second edition, but for obvious reasons the full part plastics are playing in the war effort must be reserved for a post-war edition. A chapter has been added dealing with the recent applications of plastics to thermal insulation, a field in which these new materials have already shown themselves far superior to the conventional products.

Many of the small inaccuracies which crept into the original publication have been corrected in the new edition. There are also considerably more illustrations. A brief review is provided of available technical literature. The book is well produced and should be in the hands of all those who handle constructional materials; they will find it a useful guide to the shape of things to come.

V. E. YARSLEY

THE STORY OF RUBBER

Rubber and its Use, *by Harry L. Fisher. Pp.* xvi + 128, *with a frontispiece and 20 figures. Macmillan & Company Limited, London.* 1942. 7*s.* 6*d. net.*

Rubber manufacturers in the past have been very much like the doctors—reluctant to discuss their art with their contacts. Both were inspired with the same idea, namely that the customers and patients respectively would be better off by knowing nothing about the subject. The result of this attitude in the former case is that to the layman, with one exception, 'rubber' is 'rubber,' whether it is raw or vulcanized: the one exception is 'red rubber,' which is mysteriously supposed to have good ageing characteristics quite independent of how it has been compounded. This attitude is now changing, largely owing to the fact that the rubber manufacturers' customers are now no longer only the man in the street, but technical organizations which have a habit of asking what they are buying.

In this and other ways a general interest in rubber has developed. Recent events in the Far East have greatly strengthened this popular interest and extended it even to synthetic rubber. The author of this little book states that it is the outcome of the interest shown by the audiences when he

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lectured to such varied groups as chemical societies, college student groups, high school assemblies, men's clubs, women's clubs, and luncheon clubs. What more proof is needed of the general interest in rubber at the present time? Furthermore, the author has based his book upon the questions asked by these audiences, but it should not be concluded that this has in any way narrowed the scope of the book, since every aspect and field of rubber technology have been touched upon in an interesting way.

It is a book which everyone connected with the management of rubber technical organizations has been looking for, to put into the hands of their newcomers. To the general reader it will be a mine of information. The rubber technologist, in spite of the fact that most of the contents will be well known to him, will read the book with pleasure since he will sense the enthusiasm of Dr Fisher for this fascinating subject. W.J.S.N.

DEPLETION OF THE SEA

The Overfishing Problem, *by E. S. Russell. Pp. viii + 130. Cambridge University Press, London.* 1942. *7s. 6d. net.*

Some eighty years ago the Royal Commission on Fisheries recommended that all restrictions on fishing should be repealed. The population of food fishes was then adequate to withstand the attentions of sailing vessels fishing with lines and the relatively small beam trawl. But towards the end of the last century steam began to replace sail and the powerful steam trawlers employed the larger, more efficient otter trawl. Ever greater harvests were drawn from the sea bottom. Although the effects of this were for some time offset by the development of new fishing grounds from the Barents Sea to the coasts of Morocco, yet gradually statistics of landings disclosed the dire effects of overfishing in decreased catch per day of fishing and in decline in the size of the fish.

The demonstration of the fact of overfishing, together with the discussion of preventive measures, form the joint themes of DR RUSSELL'S book. As Director of Fishery Investigations to the Ministry of Agriculture and Fisheries he writes with unique authority on this subject. His figures reveal that, despite increasing intensity of fishing, the yield in most areas remains either stationary or shows an actual decline. The reduction of fishing during the last war caused only a temporary improvement.

Dr Russell shows that two things are wrong. First, there has been too much fishing, so that the catch has fallen below the possible steady maximum which the reproductive powers and rate of growth of the fish can support; and, second, too many undersized fish are destroyed. The latter evil can be cured by an increase in the mesh of the nets, the beneficial effects of which have been experimentally proved. Only an agreed international reduction in the volume of fishing can cure the first. Such an agreement, between the United States and Canada, saved the halibut fishery of the North Pacific when this was similarly threatened.

Our fisheries are likely to be of the greatest importance after this war, when we may be thrown back more on our own resources. Dr Russell is to be congratulated on the production of a book which lays down the basis of a planned economy of post-war fishing. C. M. YONGE

SCIENCE IN THE GARDEN

The Living Garden, *by E. J. Salisbury. Pp. xi + 232. G. Bell & Sons Limited, London. Second edition,* 1942. *6s. net.*

This book is already well known to a wide circle of readers, and we welcome its appearance in a revised and cheaper edition. Few authors know more of plant-life than PROFESSOR SALISBURY, and still fewer combine this knowledge with an aesthetic appreciation of gardens and an ability to express both knowledge and appreciation in plain English. All garden-lovers who wish to understand the main principles of the plant-life they nurture will here find an interesting and reliable guide. The illustrations are numerous and well chosen, and the book as a whole is delightful: scientists will take particular pleasure in the thought that T. E. BROWN would probably have disliked it intensely.

AN INTRODUCTION TO ASTRONOMY

Foundations of Astronomy, *by W. M. Smart. Pp. vii + 268, with 119 figures. Longmans, Green & Company Limited, London.* 1942. *16s. net.*

Astronomy is a subject that has been almost entirely omitted from general science courses in Great Britain. This neglect is as surprising as it is deplorable, for astronomy touches everyday life at many points. To it is due the widespread ignorance of the simplest celestial phenomena and their consequences—such as the northward and southward movements of the Sun in the course of the year, the retardation in the times of rising and setting of the Moon from night to night, the difference between sundial time and mean time, the differences in blackout times for various towns, the phases of the Moon, the changing appearance of the sky in the course of a night and from one season to another, and so forth. To it may probably also be traced the widespread and increasing faith in the predictions of astrologers. The SPENS report made the recommendation that some astronomy should be included in all general science courses; there is hope for the future if this recommendation is implemented.

The war has not only made clear the widespread need for a background of astronomical knowledge, but has also provided better opportunities for the study of celestial phenomena. The Observer Corps, Home Guards, fire watchers and others have had excellent opportunities for observing the sky and the movements of stars, planets and the Moon. There has been an increasing demand for planispheres and popular books on astronomy. The use of the stars for providing direction at night is becoming more and more recognized, though it does not yet form part of the training of every soldier, sailor, and airman, as it should do. The Sun, Moon, stars and planets provide the best and least fallible method of air navigation.

This book, by the Regius Professor of Astronomy in the University of Glasgow, is intended primarily for students taking a first-year course in astronomy in the universities. The treatment is essentially mathematical, but no mathematical knowledge beyond elementary trigonometry and the use of logarithms is assumed. It covers, as the title suggests, and in brief compass, the basic foundations on which the whole science of astronomy has been built. One chapter is devoted to the problem of navigation and determination of position on the Earth. Numerous examples, to illustrate points of theoretical and practical interest, are provided. Anyone who has mastered this book will have acquired a solid foundation of astronomical knowledge, which can be extended according as his needs require or his inclinations suggest. H. SPENCER JONES

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Notes on contributors

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SIR ROBERT ROBINSON,
M.A., D.Sc., Hon.D.Sc., Hon. LL.D., F.R.S.

Was born in 1886, the son of the first inventor-manufacturer to make pill-boxes, surgical lint, and cotton bandages by machinery. He was educated at Fulneck School, near Leeds, and the University of Manchester. Appointed Professor of Organic Chemistry at the University of Sydney in 1912, he has since held several professorial chairs, and is at present Waynflete Professor of Chemistry in the University of Oxford. His scientific work has been concerned with the structure and synthesis of such natural products as alkaloids and anthocyanins, and with the application of electronic theories to the mechanism of reactions. He has been president of the Chemical Society of London and is a medallist of the Royal Society and many other learned bodies. A keen mountaineer, he says that his 'chief vice, a bad one, is chess.'

C. D. DARLINGTON,
D.Sc., F.R.S.

Born in 1903, he went to St Paul's School, London, but left at the age of 16 'and never regretted it.' He became a pupil of William Bateson at the John Innes Horticultural Institution in 1923, and was appointed Director of the Institution in 1939. He is well known for his original investigations on heredity, and in his *The Evolution of Genetic Systems* (1939) he used chromosome studies to establish a new point of view in biology. He prefers Lucretius, Stendhal and Lytton Strachey to most other writers, likes Mozart better than Sullivan, and detests lawyers, letter-writing and empire-builders.

J. KENDALL,
M.A., D.Sc., F.R.S.

Is Professor of Chemistry in the University of Edinburgh, though a native of the 'degenerate South,' having been born at Chobham, Surrey, in 1889. He was educated at Farnham Grammar School, the University of Edinburgh, and the Nobel Institute, Stockholm. From 1913–26 he held a professorial chair of chemistry in Columbia University, New York City, and later was Professor of Chemistry in Washington Square College, New York University. During the first world war he served as Lieutenant (later Lieutenant-Commander) in the U.S. Naval Reserve. After two years as Dean of the Graduate School, New York University, he was translated in 1928 to his present post at Edinburgh. He has made numerous contributions to the progress of chemistry, and has been particularly successful in interpreting chemistry to the layman.

SIR EDWARD APPLETON,
K.C.B., M.A., D.Sc., Hon. LL.D., F.R.S.

Is a native of Bradford, Yorkshire, where he was born fifty years ago. After occupying professorial chairs of physics at both London and Cambridge he became, in 1939, Secretary of the Department of Scientific and Industrial Research. As a member of the Scientific Advisory Committee of the War Cabinet, he is much behind the scenes in the scientific war effort. His own researches have been principally directed towards the exploration of the upper air by means of radio waves, in the course of which he led a British radio expedition (1932–33) to Tromsö, in Northern Norway, to study the effect of the aurora on radio transmission. In 1926 he discovered the ionized atmospheric layer which now bears his name, and which makes round-the-world radio communication possible. He has been active in promoting co-operation in the field of radio science, and is President of the International Scientific Radio Union. He was Hughes Medallist of the Royal Society in 1933, and was awarded the Morris Liebmann Memorial Prize of the American Institute of Radio Engineers. He has had research pupils from all over the world to learn ionospheric technique developed in this country.

F. T. BROOKS,
M.A., Hon. LL.D., F.R.S.

Born at Wells, Somerset, in 1882, he was educated at Sexey's School, Bruton, and Emmanuel College, Cambridge, of which he is now a Fellow. In 1936 he was elected Professor of Botany in the University of Cambridge after long service as Lecturer and Reader. In 1914 he was Government Mycologist in the Federated Malay States, and during the last war was Plant Pathologist in the Food Production Department. His book *Plant Diseases* is well known, and he has trained a large number of plant pathologists now serving in different parts of the Empire. He is one of the General Secretaries of the British Association and a member of the Agricultural Research Council. A keen gardener, he claims that his gardening experience has been of great assistance to him as a botanist and plant pathologist.

E. G. RICHARDSON,
B.A., Ph.D., D.Sc.

Was born at Watford in 1896 and was educated at Coopers' Company's School and University College, London. In peace-time he is the Senior Lecturer in Physics at King's College, Newcastle-upon-Tyne (University of Durham). He served in the R.A.F. in the war of 1914–18, and in this one is engaged on research in acoustics and hydrodynamics for the Services. He has specialized in the physics of sound—a subject to which he was drawn by his interest in music—and has written many books and papers on acoustics as well as on the general applications of physics.

L. P. GARROD,
M.A., M.D., F.R.C.P.

Is Bacteriologist to St. Bartholomew's Hospital and Professor of Bacteriology in the University of London. He has studied the destruction of bacteria by chemical means from many different aspects, devised new methods of testing and employing antiseptics, and consistently upheld the doctrine that the defence of the body by chemical agencies against bacterial attack is feasible. Writes on the subject of bacterial chemotherapy from a close study of its development abroad as well as at home, and from clinical experience in a large hospital.

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ENDEAVOUR
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A quarterly review designed to record the progress of the sciences in the service of mankind

VOLUME I OCTOBER 1942 NUMBER 4

Newton

The year 1942 marks the tercentenary of the birth of SIR ISAAC NEWTON, England's most brilliant scientific genius and *primus inter pares* of the greatest men of science of all time. It is fitting that, even amid the stress of war, we should pause for a moment to pay tribute to the memory of one who, 'had he flourished in ancient Greece, would have been worshipped as a divinity.' In the pages of a scientific journal there is no need to detail Newton's contributions to optics, mechanics, astronomy, and mathematics, for they are already familiar. We may, however, profitably recollect that they had such a radical effect upon the progress of science as to influence materially the subsequent course of civilization. Newton also interested himself in chemistry, and his views are discussed by DR DOUGLAS MCKIE in our present issue (p. 141).

Newton's principal characteristic was perhaps his invariable habit of thinking for himself, whether in science, in philosophy, in theology, or in the mundane matters of daily life. Possessing a phlegmatic temperament, lacking a sense of humour, and uninterested in music, poetry, and art, he was 'notoriously susceptible to the challenge of a problem' and fertile in the use or invention of mental and material tools for its solution. As need arose, he could both elaborate a new branch of mathematics—the calculus—and construct with his own hands an efficient reflecting telescope. He was, in fact, a resourceful as well as a profound thinker, with little of the eccentricity of character that frequently accompanies genius. The picture drawn of him by a modern English poet:

> Obscure, unknown, the shadow of a man
> In darkness, like a grey dishevelled ghost,
> Bare throated, down at heel, his last night's supper
> Littering his desk, untouched; his glimmering face
> Under his tangled hair, intent and still,
> Preparing our new universe—

is only partially true. He was neither obscure nor unknown; on the contrary, his supreme scientific insight was recognized instantly in England, and very quickly on the Continent of Europe. LAGRANGE described the *Principia* as the greatest production of the human mind, a verdict endorsed by LAPLACE. Moreover, Newton's power of abstract thought did not mask the fact that he possessed shrewd business ability, a talent for organization, and a forceful determination. These qualities he showed in no uncertain manner in his reforms at the Royal Mint, which he carried out with firmness of purpose and scorn for attempts at bribery. 'The ability, the industry, and the strict uprightness of the great philosopher,' says MACAULAY, 'speedily produced a complete revolution throughout the Department,' and the urgent task of recoinage was successfully accomplished. As an instance of the efficiency of Newton's work, it may be mentioned that in a very short time he increased the weekly output of silver specie from £15,000 to £120,000. From the devoted disciple of science, Newton had become the faithful servant of the State, so to remain until his death at the age of 84.

In addition to his scientific and technical activities, Newton represented the University of Cambridge in Parliament for some years, though he never attained eminence in politics. He was President of the Royal Society for nearly a quarter of a century, and one of the eight Foreign Associates of the French Academy of Science.

For us today it is salutary to recall the 'rules of reasoning in philosophy' laid down by Newton in Book 3 of the *Principia*. They are fundamental and inescapable now as when they were first enunciated in 1687; and strict adherence to them would swiftly dispel the miasma of unfounded

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hypothesis that still from time to time vitiates the atmosphere of science:

I. *We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.*

II. *Therefore to the same natural effects we must, as far as possible, assign the same causes.*

III. *The qualities of bodies, which admit neither intensification nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.*

IV. *In experimental philosophy we are to look upon propositions inferred by general induction from phenomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phenomena occur, by which they may either be made more accurate, or liable to exceptions.*

Newton himself never swerved from this austere discipline, which controlled the dynamic energy of his thought. Let men of science 'rejoice that so great a glory of the human race has appeared,' and subject themselves to the same intellectual austerity.

Correspondence

Contributions and correspondence should be sent to the editor: E. J. Holmyard, M.A., M.Sc., D.Litt., F.I.C., Imperial Chemical Industries, Nobel House, Buckingham Gate, London, S.W.1. Scientists engaged in research of an interesting or important character are invited to send short notes on work in progress and results obtained.

CO-OPERATION BETWEEN UNIVERSITIES AND INDUSTRIAL TECHNICAL STAFFS

From 'Naturalized'

The closer co-operation between universities and industrial laboratories, for which PROFESSOR ANDRADE appeals in his letter (this Journal, Vol. I, No. 1, p. 7), could be favourably promoted by linking up both types of institution through a mutual exchange of activities by their staffs. I had good opportunity to observe some results of such an exchange during my employment at various German universities in their 'democratic' period (1918–33). There, it was quite common for a substantial fraction of all specialized lectures at universities, and especially at technological faculties, to be delivered by members of the staffs of various research laboratories. These lectures provided a valuable supplement to the standard teaching programme in a more practical and specialized direction, and gave an opportunity to students who intended to go into industry of becoming familiar with recent industrial methods. Moreover, by the regular presence of industrial lecturers at the universities a personal contact was established with the university staffs. This contact frequently led to discussions of technical problems which sometimes gradually developed into regular consultations by a university professor.

Germany was in no way unique in these developments. America has, and Holland had, progressed still further in this direction. The closest co-operation between universities and industrial technical staffs is probably achieved in the U.S.S.R. Where such co-operation has been tried, it has never been abandoned. In the present emergency, our war industries are supported by all the skill and devotion which the staffs of our universities can offer. Scientific and industrial relations have thus moved into a particular type of close co-operation, and this, we may hope, will be developed into a suitable permanent form after the war.

SULPHAPYRIDINE

From L. P. Garrod, M.A., M.D., F.R.C.P.

In my article on 'Progress in Bacterial Chemotherapy' in your last issue (Vol. I, No. 3, p. 122) it was stated that sulphapyridine (M. and B. 693), the drug which has brought pneumonia within the effective scope of chemotherapy, was synthesized by A. J. EWINS. It has been pointed out to me that DR M. A. PHILLIPS was the co-discoverer of this drug with Dr A. J. Ewins, their names being associated in the literature and patents relating to it. I much regret that Dr Phillips's name was omitted in my reference to this discovery.

RUSSIAN-ENGLISH TECHNICAL DICTIONARY

From Sir John Russell, F.R.S., *Chairman, Anglo-Soviet Scientific Collaboration Sub-committee, British Council*

There is an urgent demand at the present time for an up-to-date Russian-English dictionary of scientific and technical terms. It is known that a number of Russian-English glossaries of specific terms have been compiled by various scientific institutions and individuals, and it is thought that it would be extremely helpful to scientists and technical translators if copies of these glossaries could be collected together and placed in the Science Library in London, where one complete set could be consulted.

Will, therefore, any institution or individual who has compiled a glossary of Russian scientific or technical terms, whether printed or in MS., please send a copy to the Secretary, Anglo-Soviet Scientific Collaboration Sub-committee, The British Council, 3 Hanover Street, London, W.1, who will collect these for the Science Library?

It is hoped at a later stage to compile a large dictionary, but the immediate aim is to collect the different glossaries in one place where they can be consulted. Each glossary will be known by the name of its compiler.

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British animal husbandry

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JOHN HAMMOND

British animal husbandry is celebrated the world over. Originally an art practised in the light of a shrewd though empirical judgment, the breeding of animals to meet definite requirements and conditions is rapidly becoming a science. Dr John Hammond, who has himself done much to effect this development, explains some of the breeders' aims and the methods by which they are attained.

HISTORICAL

Pioneer Breeders

The first efforts to breed superior animals were made by individual breeders, such as those by ROBERT BAKEWELL with Longhorn cattle (1750) and Leicester sheep (1755), by JOHN ELLMAN with Southdown sheep (1778), and by CHARLES and ROBERT COLLING with Shorthorn cattle (1780). Their methods were, first to collect the best animals they could for the purpose they had in view, and then to breed the best to the best. This involved in most cases close breeding and in many cases a considerable amount of intensive in-breeding [22].

That is, having decided on the type of animal they wanted, they concentrated in their herds and flocks the germ-plasm of the animals which showed these characters in greatest degree.

The Herd-books

As the reputation of their superior stock spread, others came to purchase their cattle and establish herds of these improved animals in different parts of the country. The danger then appeared that the blood, or germ-plasm, of these superior animals would be so diluted by crossing with inferior stock in the now widely distributed herds that it would be swamped, and the pioneer work in concentrating the best germ-plasm destroyed. In 1822, therefore, the first of the herd-books—*Coates' Herd-book for the Shorthorn Breed*—was instituted to record the pedigrees of all animals which traced in direct line to the original superior animals, and so to continue the idea of the pioneer breeders, viz. to concentrate the germ-plasm of the best animals. These herd-books, and the breed societies which eventually ran them, then set up standards of excellence for the breed in order to attempt to define in words the object for which the animals should be bred and selected, that is to get all the breeders to have the same objective in view. Needless to say, the world is never static and commercial requirements change with time; standards of excellence therefore have been changed slightly since their institution. Moreover, certain individual breeders from time to time, even within the framework of these herd-books, had ideas of their own as to how the evolution of the breed should proceed, and, although the pedigree was continued, they picked out and concentrated in like manner certain types which they considered better suited to the times in which they lived. Thus, concentrations of germ-plasm of rather different types were produced in Shorthorn cattle, by the same in-breeding methods, by the BOOTHS (THOMAS, JOHN, and RICHARD), by THOMAS BATES, and by AMOS CRUIKSHANK in turn.

The Show-yard

Another method by which uniformity of purpose by breeders within the herd-book was achieved was by the show-yard system. Under this system breeders of outstanding ability were asked to select and give prizes to those animals which most nearly approached the ideal to which the efforts of the breeders were directed. All the breeders in the herd-book society were thereby given a visual demonstration of the objective towards which they should strive. The first of these shows was for fat stock, that of the Smithfield Club, founded in 1798 [1]. One of its purposes was to develop early maturity in livestock, thus forwarding the interests of both feeder and butcher. How well it did this is shown, for example, by the fact that at the 1874 show the best Devon steer, weighing 1,680 lb., was 4 years old, whereas at the 1925 show the best Devon steer weighed 1,669 lb. at 2 years 10 months old.

In 1837 the Royal Agricultural Society's Show was founded for breeding stock. A large number of local and county shows now serve as preliminary

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rounds for this premier event of the breeder's year. One criticism [19] which has been made of these shows is that fancy points, such as colour, shape of horns, etc., received too much attention. These characters, which are for the most part of the simple Mendelian type of inheritance [6], form the 'trade mark' of the breed and are a guarantee of its purity, for, with our present-day knowledge of inheritance, their appearance reveals any admixture of outside blood. Some criticisms of the show-yard [19] seem to imply that it is the only method of livestock improvement adopted by breeders, whereas in fact, as the present article will show, it is only one link in the chain of methods employed.

Production Tests

In order to ensure that the various breeds of livestock were bred to suit commercial requirements, tests of production were instituted at the shows. The Smithfield Club [1] has kept complete records of carcass tests for meat-producing animals since 1895, the classes being judged by butchers to ensure that the improvement of the animals followed the changing tastes of the public for quality in meat. Some breed societies, such as the National Pig Breeders' Association, have run their own carcass tests for bacon and for pork, these being judged on a score-card system so as to show those who do not win prizes in what respects their animals are failing to meet trade requirements. Similar tests for bacon carcasses have been held at the London Dairy Show since 1922. Some breed societies, too, such as the Large White, keep fecundity records of their sows. For dairy cattle, milking trials were instituted at the principal shows, those at the London Dairy Show having been held annually since 1876 [12]; similar tests are also carried out at the Royal Agricultural Society's Show [13].

To assist breeders to select their cows for milk production, lactation milk yields of cows were recorded by owners and breed societies, the Ayrshire and Jersey being among the first of these to operate. Later, in 1910, a uniform system of milk recording throughout England and Wales was instituted by the Board of Agriculture, and registers were compiled of cows with consistent high production; butter-fat tests were also made. In addition, the actual quantity and quality of the butter produced by individual cows have been tested at the Dairy and Royal Shows; thus, besides fat percentage, other factors are considered such as size of fat globule and the colour of the butter, of special interest to the butter-producing breeds like the Jersey and Guernsey.

In recent years scientific workers have been trying to devise methods for measuring more accurately the various factors which go to make for quality in meat and dairy products, so as to facilitate the work of the breeder in selecting his stock.

Progeny Tests

It was a practice among the pioneer breeders to 'let out' some of their young bulls or rams each year to other breeders, so as to be able to see the quality of their progeny before they used these sires on their own selected females. This 'progeny testing' of sires, which is now widely advocated on the basis of genetic experiments [6], was later introduced into the show-yard, where, at the Royal and Dairy Shows, prizes were given for a collection of animals the progeny of a single bull. Another form this progeny testing has taken is the publication of the names of the sire and dam of animals winning in the carcass tests at shows, such, for example, as those in the Large White Herd-book. Registers of merit for bulls which have produced a given number of daughters of outstanding merit are published by the Dairy Shorthorn, British Friesian, Jersey, Guernsey, and other herd-books. Recent advances in the science of artificial insemination have now made it possible greatly to extend the use of such progeny-tested males and so spread the best germ-plasm widely throughout the breed [23]. For example, not only can some ten cows be inseminated from a single ejaculation by a bull, but by storing the semen at low temperature and preventing exposure to the air, it can be sent by air mail over long distances, so that cows in Holland and ewes in Poland have conceived to sires in England [4] [24].

Advanced Registers

As long as the destinies of the breed are in the hands of a small number of breeders it is comparatively easy to keep up a high concentration of the best blood and germ-plasm within the breed; such breeds have shown a rise in the coefficient of in-breeding, i.e. the percentage of actual out of potential ancestors in the pedigree [2]. When, however, the breed is in the hands of a very large number of breeders, some of them inexperienced, it is a much more difficult matter to know where the best germ-plasm is to be found. To overcome this difficulty some

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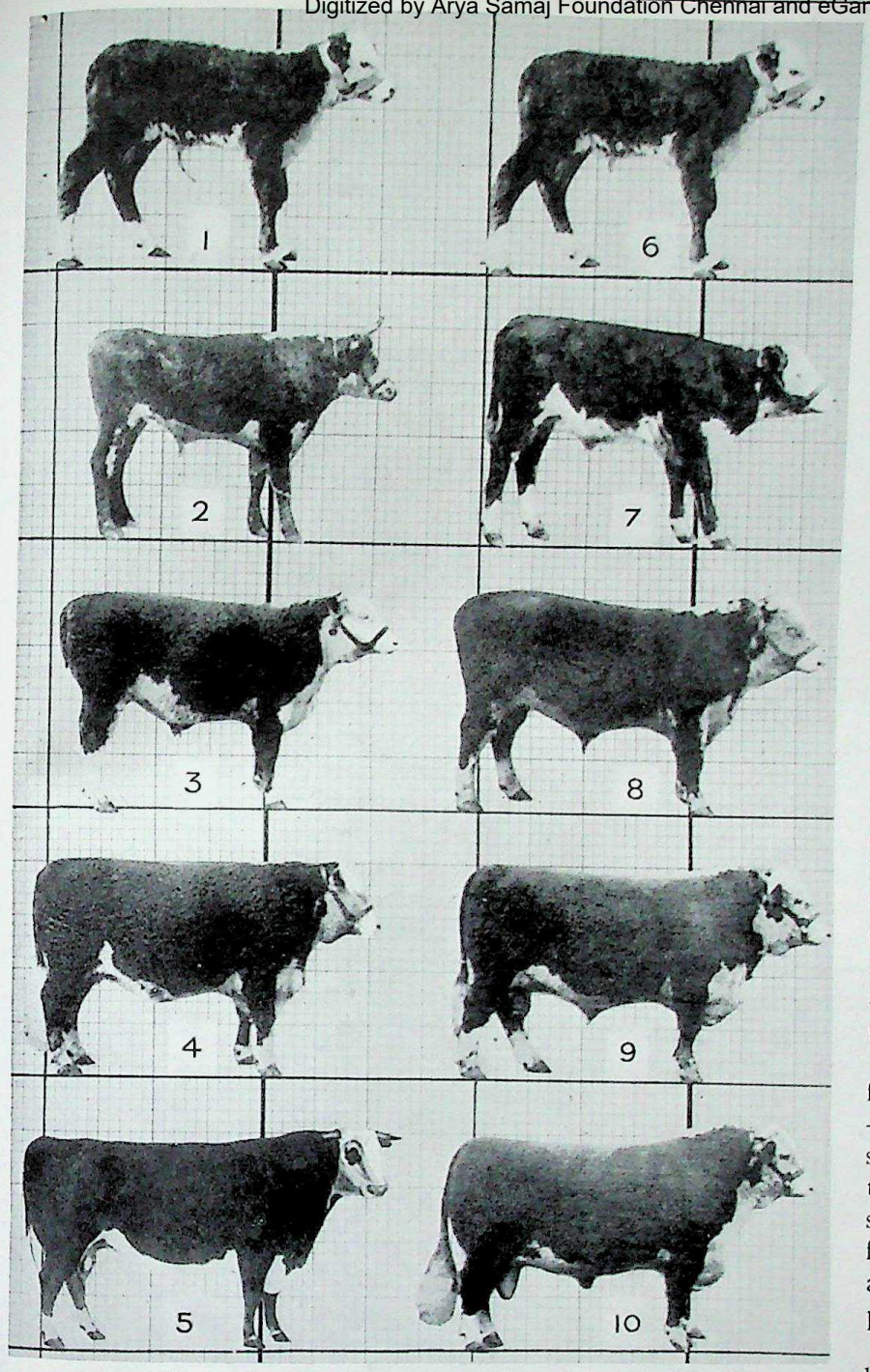

FIGURE 1 – *Changes in the body proportions of Hereford cattle. In order to show changes in proportions, as distinct from size, all the photographs are reduced to the same height at the shoulders.*

1. Heifer, 2 days.
2. Steer, 30 months, grown on low level of nutrition.
3. Steer, 11 months, grown on high level of nutrition.
4. Steer, 22 months, grown on high level of nutrition.
5. Bull of 100 years ago.
6. Heifer, 2 days.
7. Bull, 5 weeks.
8. Bull, 13 months.
9. Bull, 22 months.
10. Bull, 5 years.

herd-books (British Friesian, Jersey, Guernsey, etc.) have started Advanced Registers, or Registers of Merit, that is, registers of animals which have outstanding records of performance, so that they can be used for breeding bulls. This is also achieved in another way by the Dairy Shorthorn Society, which does not allow a bull to be registered unless the dam has yielded more than a given amount of milk.

OBJECTS OF BREEDERS

The very many breeds that exist in Great Britain are the result of the interactions between two main objects that the breeders had in view—a breed for every purpose and a breed for every type of environment. Thus in cattle, for example, there are breeds for beef production—the Beef Shorthorn, Hereford, Aberdeen-Angus, etc., for good lowland environmental conditions; and others—the Galloway, Highland, and Welsh—for cold rough mountainous conditions; breeds for dual purposes (milk-beef), the Dairy Shorthorn for good land and the Red Poll for poor light dry land; breeds for milk, the Ayrshire and British Friesian; and breeds for cream and butter, the Jersey and Guernsey.

With sheep the breeds range from the Welsh and Blackfaced—improved mutton breeds suited for wet and cold mountainous districts—to the Hampshire and Suffolk, improved fat lamb breeds suited to arable areas growing crops for folding purposes.

The various breeds have thus been closely adapted to the conditions under which they are to live and have, therefore, in addition to production, a quality called 'constitution,' that is, the power to live long and thrive under these conditions, a quality without which long-continued high production is not possible [5] [6].

BREEDING METHODS

In breeding for a purpose the breeder must be

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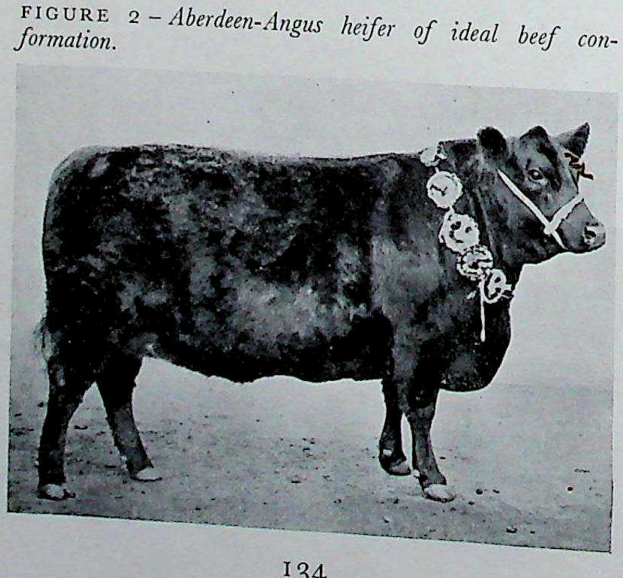
in close touch with those who are using his product commercially, and this has been done by the methods already outlined. He also has to study the effects of environment, feeding, and the different conditions of management on the amount and quality of the product he is breeding for. Having found the optimum conditions, he arranges to breed and select his animals under these conditions, so that he is then able to pick out and breed from those animals which show in the highest degree the qualities he is striving after. By this means he is able to direct the evolution of his breeds. In any but optimal conditions for production, the production is limited by the environment or food supply and not by the genetic capabilities of the animal; hence proper genetic selection cannot be made. Thus it will be seen that the breeding methods are not merely static, in reproducing the best which has gone before, but evolutionary, in raising the level of production and quality to higher levels than ever existed previously. For this purpose the breeder not only uses the results of the science of genetics, which enable him to eliminate unwanted characters, concentrate the germ-plasm of desirable animals, and pass this on to future generations with a high degree of certainty; he also employs the results of the sciences of animal nutrition and animal physiology, which tell him what are the optimal conditions for the production by the animal of the qualities he desires to breed for. Examples of the way in which these are used will be given below.

Beef

For beef purposes the butcher requires an animal which will yield him a good percentage of carcass, i.e. one in which the proportions of offal parts such as head, legs, intestines, etc., is small, one which has a great thickness of muscle as compared with length of bone, and one with a smooth covering of fat over the whole carcass. These things develop as the calf grows up, and the extent to which they develop determines the value of the animal for meat purposes. That is, as the animal grows up it not only increases in size, but also changes in the proportions and composition of its body (see figure 1).

At birth the calf is all head and legs, while as it grows up the loin and buttocks grow at a faster rate than the head and legs, and so the more valuable parts increase in proportion to the offal parts. If the animal is reared on a low plane of nutrition, however [20], it grows up without much change in body proportions and so has a poor meat value (compare Nos. 2 and 4, figure 1). This is because the early-maturing parts of the body—head, legs, bone, heart, liver, and lungs—have first call on the nutritive substances available; thus on a limited food intake these parts continue to grow, while the growth of the later-developing and more valuable parts, such as the loin and buttocks, is inhibited. Localities, therefore, such as range areas, where the conditions of nutrition are uncertain, are unsuitable for breeding improved strains of beef cattle; under such conditions, full development of the genetic possibilities of the animal for meat production is not possible and proper selection cannot be made. On the other hand, in good grassland areas or in districts where plenty of supplementary feeds are available, it is possible to push forward the animal to full development of its meat qualities. By doing this with successive generations, and selecting and breeding from those which prove best, the proportions of the body develop not only at an earlier age but also to a further extent. Thus the adult Hereford bull of 100 years ago (figure 1, No. 5) is no more advanced in its body proportions than is a present-day bull at a year old. In the opinion of the judges at the Smithfield Show the Aberdeen-Angus is the nearest approach yet obtained to the ideal beef conformation (figure 2).

FIGURE 2 – *Aberdeen-Angus heifer of ideal beef conformation.*



Mutton and Lamb

How the British breeds of livestock have been improved for early maturity can be seen by comparing the changes in proportions which occur in the growth of the wild sheep, the Mouflon, with those

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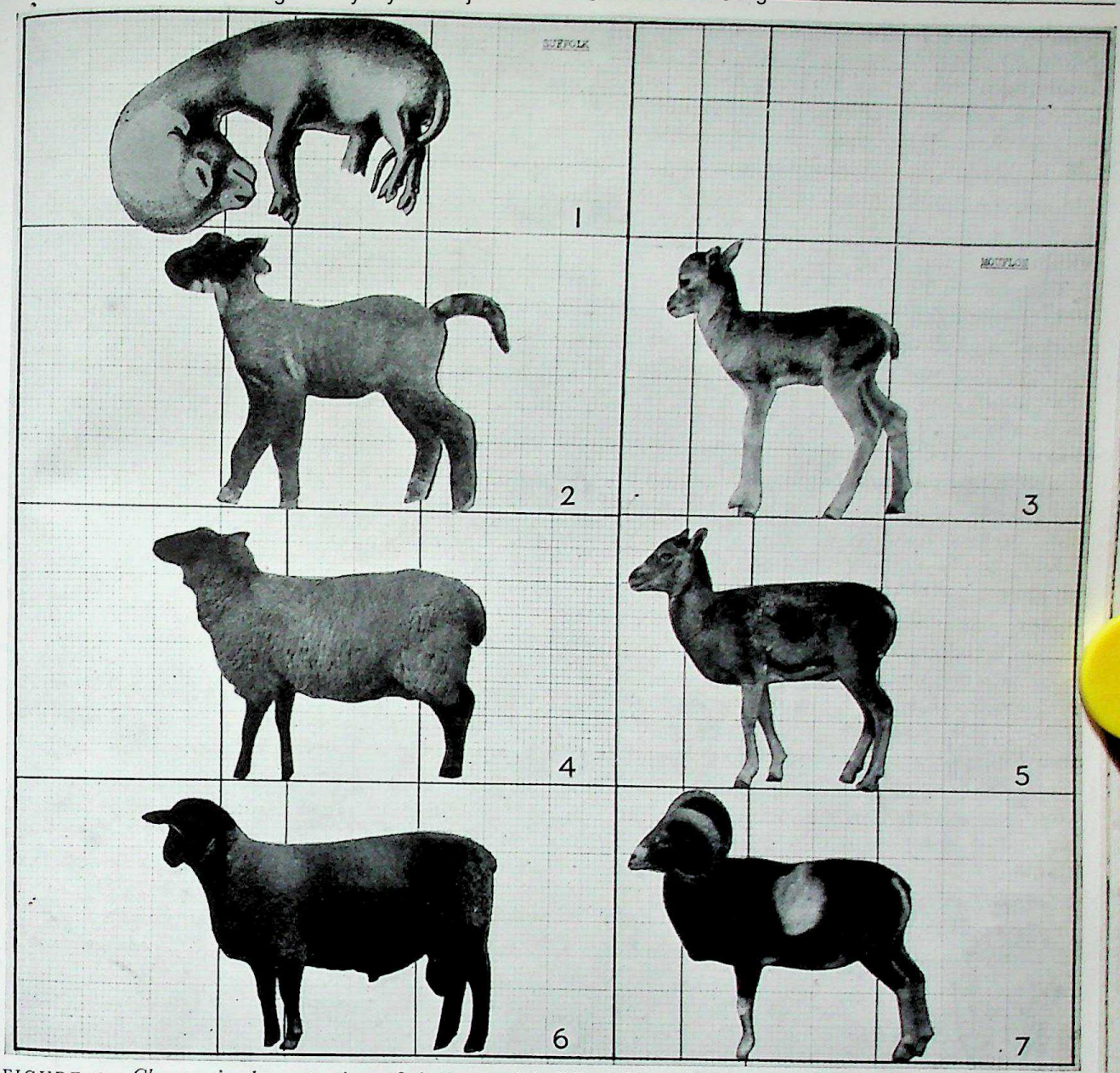

FIGURE 3 – *Changes in the proportions of the improved Suffolk* (left) *and unimproved Mouflon* (right) *breeds of sheep as they grow up. Each is reduced to the same shoulder height so as to show differences in proportions as distinct from differences in actual size.*

Top: Embryo of 2 months *Second line:* 4 days old. *Third line:* Adult ewe. *Bottom:* Adult ram.

which occur in an improved breed like the Suffolk (figure 3).

Early maturity from the butcher's point of view is not merely increase in weight for age, but consists of a speeding-up of the changes occurring in the proportions of the body. From the butcher's standpoint the animal is not fit to kill until the proportion of fat and muscle to bone reaches a high level; this ratio is closely related to the shape and proportions of the animal, and so he uses visual appreciation of shape as a guide. For example, an animal *shaped like* the Suffolk lamb at birth (figure 3) yields for every 100 lb. of live weight only 31 lb. of edible muscle and fat, whereas one *shaped like* the adult Suffolk ram yields double that amount, viz. 62 lb. [7]. From figure 3 it will be seen that the shape of the adult Mouflon ewe—and so its yield of edible meat—is only a little in advance of our improved breeds at birth. That is, we have increased the early maturity of improved breeds so that at about 2–3 months old they will yield as much edible meat as the unimproved sheep in adult life. As previously explained, under Beef, all this has been

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done by rearing the animals on a high plane of nutrition and by picking out and breeding from those animals which are the most early-maturing, i.e. those in which the changes in body proportions occur most rapidly. In this way British breeders have not only obtained more early maturity, but have pushed forward the development of meat qualities in the adult animal to higher levels than have ever been reached before. All this has involved a considerable amount of trouble and expense in growing special crops for folding, etc., and in finding foods which would increase the rate of growth—especially in the ram lambs, for one good ram can leave many more offspring than one good ewe. These general principles, as illustrated by the above example, apply also to cattle and pigs bred for meat purposes.

The breeder of livestock has to keep in close touch with prevailing trends in the public demand for quality in meat. This, as mentioned above, is ensured by appointing butchers as judges at the carcass tests at shows. Recently, however, overseas breeders who are unable to exhibit at shows in Britain have required some guidance in this matter, and standards of excellence for carcasses on the score-card system have therefore been evolved to meet their requirement [9] [11] [16]. They can consequently run carcass tests, based on the British public's demand, in shows in their own countries. Figure 4 illustrates one example of such standards for lamb, for which the great demand is now for carcasses of 28 to 36 lb. Ideal and unsuitable carcasses are illustrated in the score-card system produced by the Australian Meat Board.

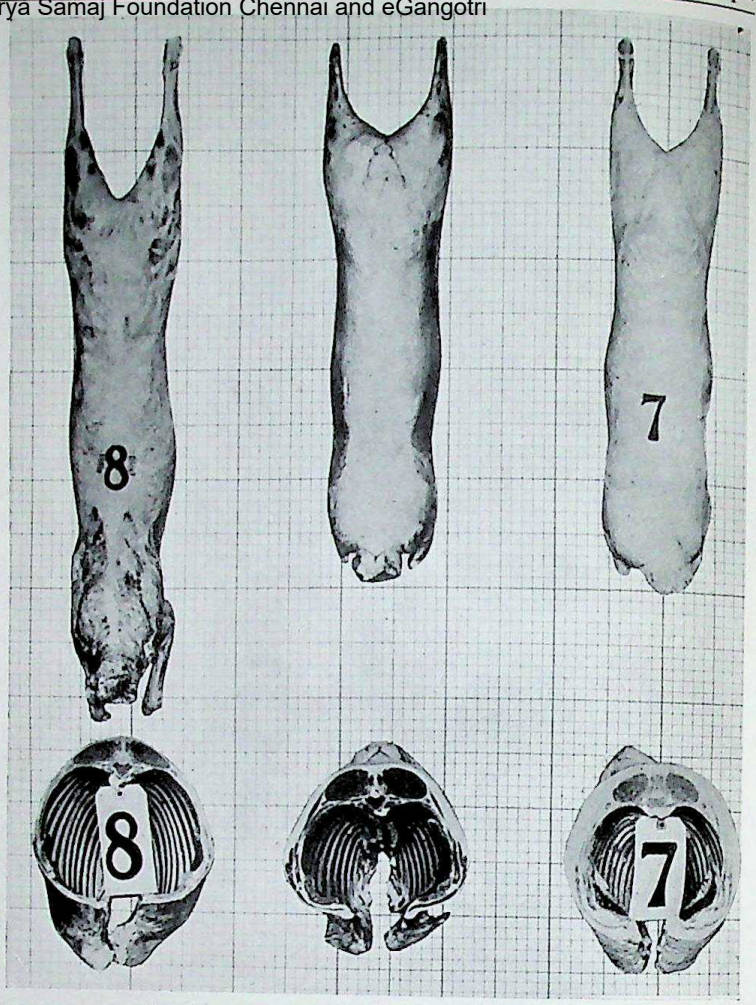

FIGURE 4 – *Lamb carcasses of 28-36 lb., illustrating the method of combining photographs with score cards to show breeders the requirements of the meat trade.*

Pts.		*Unsuitable*	*Suitable*	*Unsuitable*
	EXTERNAL:			
1.	Legs, short boned and well filled ..	1	30	21
2.	Fat covering sufficient on lower part of legs	2	10	10
3.	Loin, wide and full	3	10	6
	INTERNAL:			
4.	Depth of fat over loin, correct proportions	5	20	8
5.	Eye—muscle, depth and size	4	15	7
6.	Ribs, light with high proportion of lean	5	10	2
7.	Colour of lean, not too dark. Texture of lean, fine grained	2	5	5
	Total	22	100	59

As previously stated, the breeder has to make selection of his animals under the conditions which best develop the characters he is breeding for. Scientists have been at work to discover what these are, and one example can be given of the optimum conditions suited for the production of fat lamb carcasses of 30 lb. VERGES [21] fed lambs from the third month onwards of foetal life (by controlling the food intake of the pregnant ewe for two months before the birth of the lamb) so as to make their growth-curves conform to certain predetermined curves (see figure 5).

Those which were caused to grow as quickly as possible reached the required 30 lb. carcass weight in 56 days (figure 6, No. 47) and made the most suitable carcasses—short-boned with great depth of flesh; while those which were caused to grow slowly reached the required 30 lb. carcass weight in 294 days (figure 6, No. 38) and produced the worst carcasses, with long bones and

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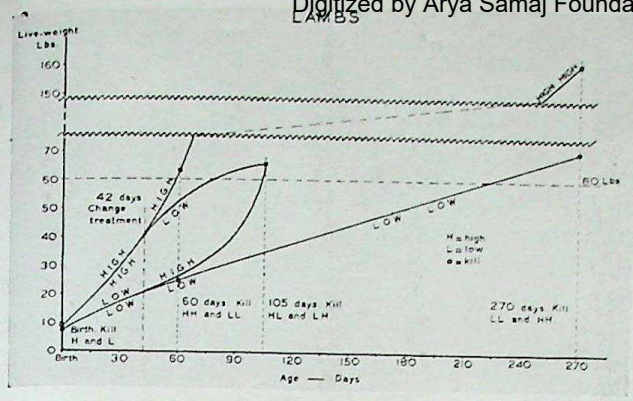
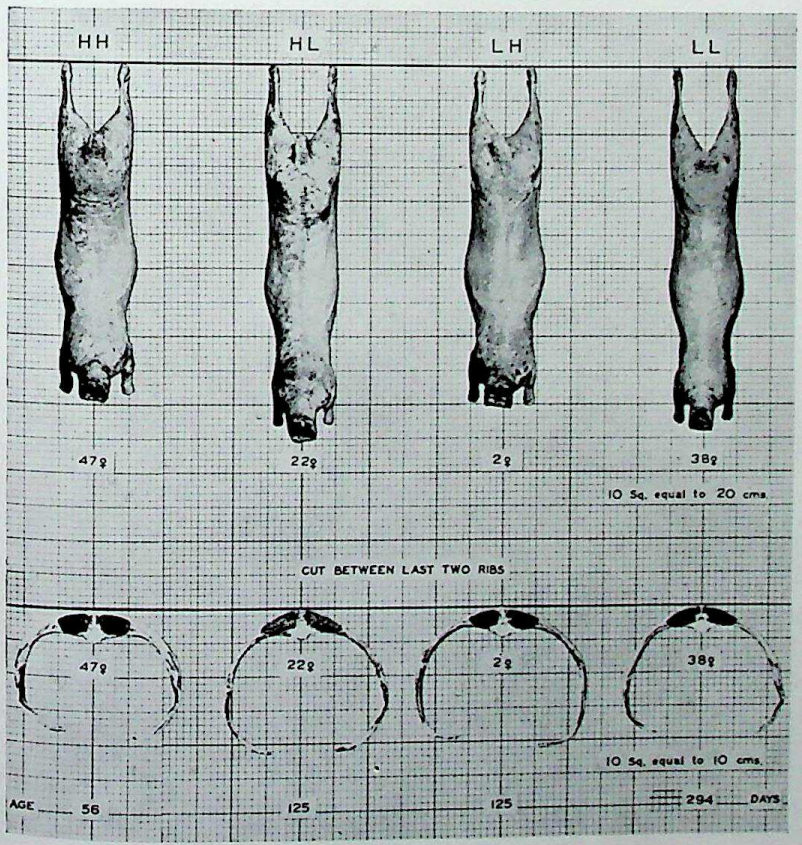

LAMBS
Live-weight Lbs
42 days Change treatment
60 days Kill HH and LL
105 days Kill HL and LH
270 days Kill LL and HH
Birth Kill H and L
Age — Days

FIGURE 5 – *Plan of Verges' experiment with lambs to determine how the shape of the growth-curve, controlled by feeding on different planes of nutrition, can affect the proportions and composition of the carcass. Carcasses of lambs with these four different types of growth-curve are shown in figure* 6.

but thin flesh over them. The second-best carcass was made by those which grew slowly at first and were then finished quickly (figure 6, No. 2) at 125 days old. Those which were killed at the same age, but had been made to grow quickly at first and finished slowly, gave the second-worst carcasses (figure 6, No. 22). They grew a large frame, but the poor rate of growth towards the end of the feeding period prevented a sufficient covering of flesh and fat. No. 47 (figure 6) is typical of the optimum conditions for those who are breeding for fat lamb production (cf. figure 4), while No. 2 is typical of the optimum conditions for those who are breeding for mutton production.

The problem of evolving improved breeds of mutton sheep for cold, wet, mountainous, and poor land areas is much more difficult, for in addition to improvement in meat quality the breeder must develop hardiness of constitution in his animals. The British breeder has always striven to breed all his animals with good constitutions, and those destined for mountain areas form a special case. On the one hand, selection for hardiness cannot be obtained without keeping the animals under the appropriate severe conditions, and, on the other hand, selection for improved mutton qualities cannot be obtained unless the animal is reared on a high plane of nutrition. Breeders of such sheep as the Welsh and Blackfaced therefore breed and select their ewes under the rigorous climatic conditions of the mountains, but breed and select their rams in small flocks kept under better nutritive conditions. By using such rams on hill flocks and selecting their progeny for hardiness, a combination of hardiness and improved mutton qualities has been obtained. Breeding sheep and cattle suitable for the hot, humid conditions of the tropics, however, has not been possible, for the climate has not been available in Britain. Cattle bred under temperate climates are liable to a raised metabolism and so to lowered production under tropical conditions [17]. Crosses between these and Zebu breeds which have been evolved in the tropics are therefore being undertaken to build up breeds suited to tropical conditions [8] [14].

FIGURE 6 – *The effect of the shape of the growth-curve (see figure* 5*) on the carcass proportions of lambs at the same carcass weight* (30 *lb.*). *Compare these with the requirements of the meat trade (figure* 4).



Pork and Bacon

The development of breeds of pigs for pork and bacon has followed much the same lines as in other animals. The present demand for pork carcasses is mainly for those pigs of about 100 lb. live weight, while for bacon a heavier pig of about

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200 lb. live weight is required. The problem has thus been to breed pigs which would provide carcasses with the correct proportions of muscle, fat, and bone at these weights. For example, the Middle White has been developed as an early-maturing breed which attains suitable proportions for killing at 100 lb. live weight for pork. The Large White, on the other hand, a larger breed, is rather later in maturing and attains suitable proportions for killing at 200 lb. live weight for bacon (figure 7).

The conditions of growth necessary for developing these two different types have been studied by MCMEEKAN [15]. He grew pigs from the same litter along predetermined growth-curves by changing the plane of nutrition at different phases of the animal's life, in a manner similar to that used by Verges for lambs (see figure 5). The optimum conditions for producing a pork pig were found to be rapid growth from birth onwards; for bacon, on the other hand, the optimum conditions are rapid growth to 16 weeks old and then slower growth by restricted rationing, so that the 200 lb. live weight is attained in about 200 days (figure 8, No. 85). By growing the animal slowly to 16 weeks old and then putting it on a high plane of nutrition to reach 200 lb. live weight in about 200 days, a lard type of pig is produced (figure 8, No. 89).

It is by keeping the animals under such conditions of management and feeding, and by selecting and breeding from those which respond best to the treatment, that the different types of pigs have been produced for the special purposes for which they are required. A typical example of the type that is now considered ideal for bacon purposes is shown in figure 9.

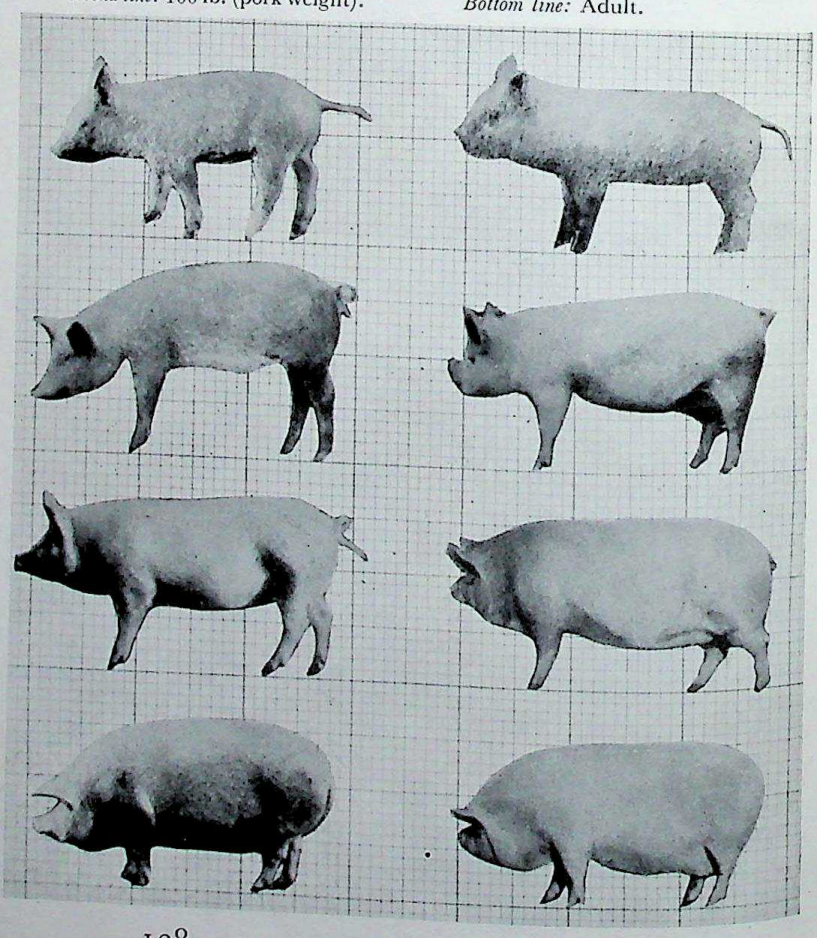
Milk and Butter-fat

Before proper selection of breeding stock can be made, it is essential that the production should be limited by the genetics of the animal and not by limitations in food supply. In order to obtain the highest production of milk of which the animal is genetically capable it is necessary that the food should be ample in amount and properly balanced so far as protein and mineral content are concerned.

The fine pastures of Great Britain ensure this during the spring months of the year by the young succulent grass with its high protein and mineral content and lack of fibre, which substance, although it fills, fails to feed the animal. As studies of milk records have shown [18], the foods fed at other times of year frequently fall below the optimum requirements for milk production. The careful compounding of suitable supplementary rations for dairy cows has therefore been the subject of much experiment and study, until at the present time these supplementary feeds can support continued milk yields of 20,000 lb. and upwards per year. Within such a nutritional environment it became an easy

FIGURE 7 – *The changes in the proportions of the pig as it grows up. In order to compare changes in proportions as distinct from changes in size all the animals have been reduced to the same height at the shoulder. The pork breeds such as the Middle White* (right) *pass through the growth-changes more quickly than the bacon breeds such as the Large White* (left), *so that while the former attain the required body proportions at* 100 *lb., the latter do not attain these proportions until they are* 200 *lb.*

Top line: 1 week old. *Third line:* 200 lb. (bacon weight).
Second line: 100 lb. (pork weight). *Bottom line:* Adult.



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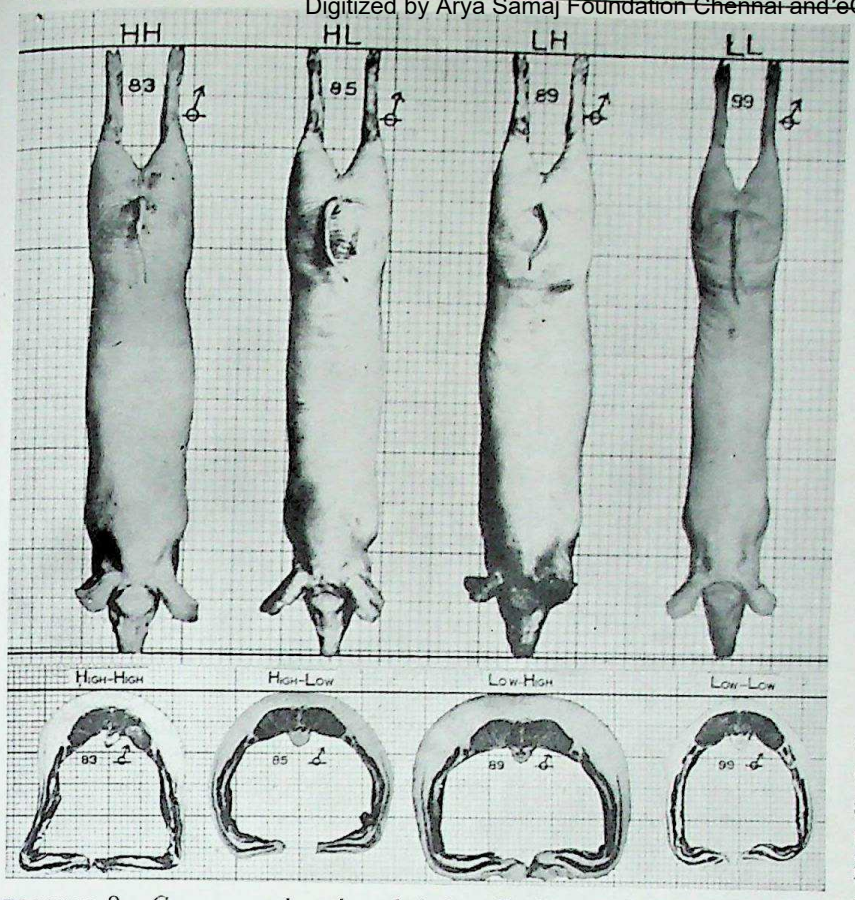


FIGURE 8 – *Carcasses and cut through the last rib of bacon pigs* (200 *lb.*) *grown along predetermined growth-curves by controlling the plane of nutrition at different stages of growth. All photographs reduced to the body and same 'eye-muscle' length.*

High-High: Quickly grown throughout. 168 days old.
High-Low: Quickly grown to 16 weeks; afterwards grown slowly. 196 days old.
Low-High: Slowly grown to 16 weeks; afterwards grown quickly. 196 days old.
Low-Low: Slowly grown throughout. 315 days old.

High-High produces the pork type, though because it has passed the right weight (100 lb.) it is now too fat. *High-Low* produces the bacon type. *Low-High* produces the lard type.

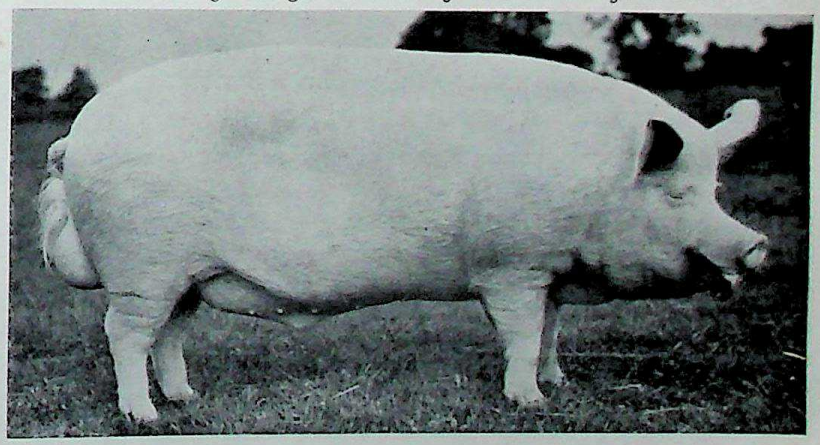
matter to select for breeding purposes cows which have a high development of udder tissue. Many other problems naturally followed this increase in udder tissue. For example, as the rate of milk secretion goes up, the pressure of milk within the udder increases and slows down further production [10]; milking therefore had to be undertaken more frequently before higher levels could be reached. Similarly, attention had to be paid to the elasticity of the skin and udder tissue for the same reason, and to the shape of the udder, so as to ensure a long period of useful production.

In addition to these methods, in breeding for butter production the making of butter from individual cows has played a part in increasing fat-globule size and in the better creaming of the milk. Moreover, the colour of the butter-fat has been improved in such breeds as the Jersey and Guernsey by supplying the necessary substances—plant pigments—for its production. Without these pigments, proper selection of breeding stock for this quality cannot be made [25]. These qualities in milk have come to be of importance commercially, now that milk is sold to the consumer in glass bottles and the cream-line and colour of the contents can be seen.

CONCLUSIONS

The principles of modern genetics have been and are being incorporated into the administrative scheme of herd-books and registers, as well as in the practice of individual breeders. These principles are used to concentrate the most desirable germ-plasm and pass it on to future generations with a high degree of certainty, as well as to eliminate undesirable characters. In addition, each relevant new discovery is utilized to create an environment optimal for the production of desired characters. By selecting within this optimal environment the breeder can raise the level of production and quality in his animals to higher levels than were formerly attainable.

FIGURE 9 – *Large White boar of ideal bacon conformation.*



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A message from Russia

Welcome evidence of the interest aroused by ENDEAVOUR in Russia comes in the form of an article cabled to us by the Secretary of the Soviet Scientists' Anti-fascist Committee in Moscow. The article, which is written by PROFESSOR NIKOLAI DERZHAVIN, was unfortunately received too late for inclusion in the current issue and is moreover non-technical in character. At a time when the eyes of the world are fixed on the grim, heroic struggle of the Russian peoples against our common enemies, we must quote Professor Derzhavin's declaration that—

> Every day of the struggle . . . makes us stronger, steels our resistance, multiplies our energy, and increases our determination to bring this combat to a decisive and victorious conclusion, with the complete destruction of Hitler's army and the elimination of Hitlerism. In this we are more than ever determined, for we firmly know that ours is a righteous cause and that the insidious foe who so grossly miscalulated will be routed without fail. We know that together with us in this titanic struggle, for which history furnishes no parallel, are all the oppressed peoples of Europe and all progressive humanity, led by the great democratic powers Great Britain and the United States. The realization of this fact not only enhances our fighting power but fortifies our confidence that the Nazi ulcer on the body of Europe and its menace to all national freedom will be wiped from the face of the earth once and for all.

We are greatly honoured by the compliment implied in a cabled contribution from such an eminent source, and regret that we are unable to make more than brief reference to it. We are, however, happy to be able to announce that it has been decided to publish ENDEAVOUR in the Russian language, as a small tribute to our great Ally and a slight contribution to the future of Anglo-Russian scientific relations.

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Newton and chemistry

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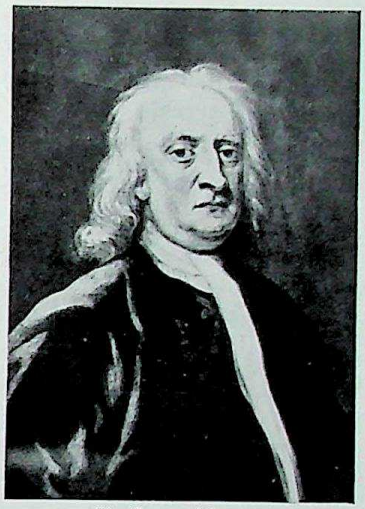
DOUGLAS McKIE

Newton's great contributions to physics and mathematics overshadow his views on chemistry. His interest in this branch of science, however, is shown by numerous autograph manuscripts found among his papers. Dr McKie suggests that Newton attempted to discover the laws of chemical attraction, and to parallel in the microcosm of chemistry his fundamental work in the macrocosm of mechanics.

ISAAC NEWTON was born in the manor-house of Woolsthorpe-by-Colsterworth, a few miles south of Grantham, Lincolnshire, on Christmas Day, 1642. He was the posthumous child of ISAAC NEWTON and his wife, HANNAH AYSCOUGH. He was educated at the King's School, Grantham, and entered Trinity College, Cambridge, in June 1661, graduating in January 1664/5.



Sir Isaac Newton.
(From the painting by Van der Bank, by courtesy of the Royal Society.)

Interrupted in his further studies through the dispersal of the students owing to an outbreak of the plague, Newton returned to his home at Woolsthorpe. There, in enforced vacations extending from the summer of 1665 to the spring of 1666/7, he invented the differential calculus and discovered the composition of light and the law of universal gravitation. Any one of these would have meant immortal fame. Yet all three fell to Newton when he was in the twenty-third and twenty-fourth years of his age. Returning to Cambridge, he was elected a Fellow of Trinity College, took his M.A. degree, and in 1669, in his twenty-seventh year, was appointed Lucasian Professor of Mathematics in succession to his teacher, ISAAC BARROW, who wished to relinquish the Chair in order to study theology. In 1687 Newton published his *Philosophiæ Naturalis Principia Mathematica*, that sublime achievement of the human intellect.

But Newton, like many lesser men, loathed the drudgery of mathematical work, and it was to his relief that he was appointed Warden of the Mint in March 1695/6, and then Master in 1699, when the recoinage of the silver was completed. The change from Cambridge to London seems to have been much to his liking. He was elected President of the Royal Society in 1703 and re-elected at successive intervals until his death. He took an active part in the Society's meetings and conscientiously discharged the duties of his office. He died on 20th March, 1726/7, in his eighty-fifth year, hale and vigorous almost to his last days. His body lay in state in the Jerusalem Chamber in Westminster Abbey from 28th March, and on 4th April was buried in the Abbey near the entrance to the Choir.

Newton's achievements in mechanics are generally known to scientific readers. His chemical studies are less well known and often dismissed as 'alchemical.' Newton was very far from being a man of remote academic interests. He had a very practical mind; in his boyhood he made mechanical toys, clocks, and sundials; he was skilled with his hands, possessing, like so many scientists of the first rank, that priceless gift of 'handicraft'; and he habitually noted down, from his schooldays, interesting chemical 'recipes' that he met with. His interest in chemistry probably began when he was boarding at the house of the apothecary CLARK during his schooldays in Grantham.

This early interest in chemistry continued after Newton went to Cambridge. In 1669, the year in which he became Lucasian Professor, he bought chemicals, flasks, furnaces, and a *Theatrum chemicum*[1]. About this time, too, he experimented on the production of alloys suitable for use in the mirrors of the reflecting telescope that he had

[1]Newton's copy of this book, with numerous annotations in his handwriting, was offered for sale some years ago by a London bookseller.

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designed. He fitted up one of his rooms in Trinity as a chemical laboratory and devoted much time to study and experiment. When his friend ASTON was leaving on a foreign tour in May 1669 and sought his advice, Newton advised him to observe, among other things, the methods of mining, smelting, and refining; to take note of any transmutations he might meet with; to try to find out whether 'at Schemnitium in Hungary ... they change iron into copper by dissolving it in a vitriolate water'; and to investigate whether the waters of certain rivers in the mining regions of Central Europe contained any gold, and whether this was recovered by means of mercury.

A stone from the King's School, Grantham, on which Newton cut his name.

(By courtesy of the Committee of the Grantham Museum.)

So Newton maintained his interest in chemistry, notably in the period when he was composing the *Principia*. Wearied with the burden of that supreme task, he seems to have turned to chemical experiments as a relaxation. HUMPHREY NEWTON, his assistant at that time, says:

> About 6 weeks at spring, and 6 at the fall, the fire in the elaboratory scarcely went out, which was well furnished with chemical materials as bodies, receivers, heads, crucibles, etc., which was made very little use of, the crucibles excepted, in which he fused his metals; he would sometimes, tho' very seldom, look into an old mouldy book which lay in his elaboratory, I think it was titled Agricola de Metallis, the transmuting of metals being his chief design, for which purpose antimony was a great ingredient.

Master Humphrey was not well informed. No one would consult AGRICOLA on the transmuting of metals; that noble old metallurgist was not fond of alchemists and dowsers and such-like. And Master Humphrey, and others who have whispered so knowingly to us after perusing his words that the great Newton himself was an alchemist, might have recalled that antimony was used in alloys for metal printing types long before Newton's day. It seems that antimony is a suspicious substance for men of reputation to touch; perhaps it still has some lingering association with JEZEBEL.

With regard to theory, Newton was a follower of the Netherlands chemist, JOHANN BAPTISTA VAN HELMONT (1577 or 1580–1644), who discovered the materiality of gases and revived the theory, first propounded by THALES OF MILETUS (*c.* 624–565 B.C.), that all substances were produced from water. BOYLE, though a great admirer of van Helmont, was sceptical about this theory, as about most things; but Boyle's corpuscular explanations of chemical phenomena deeply influenced Newton. Boyle was successfully using not, of course, our present atomic theory, but the Greek atomic theory, which saw in the various substances in Nature so many aggregates of differing numbers and arrangements of ultimate identical 'uncuttables' or atoms. In this view, all atoms were qualitatively the same; and therefore matter was transmutable. It is in this sense of transmutability that Newton was an 'alchemist,' and so also is the modern atomic physicist. But both are worlds away from the Philosophers' Stone and the Elixir of Life. As for the wide evidence we have of Newton's copying of extracts from alchemical authors, the significance of this has been over-emphasized. Boyle did likewise, and so have others. Such books were often rare. Moreover, Newton copied from other books as well. And his library contained chemical works other than those of alchemists. Alchemical books often gave valuable practical information on the properties of the metals.

Newton took his chemistry from van Helmont and Boyle. His world was a world of atoms and void, in which all substances were produced from water, a world of flux that would have delighted the soul of HERAKLEITOS. Let us consider some of its interesting detail. Newton's contemporaries and predecessors had discussed the apparent dissipation of matter from the tails of comets. Newton thought that gravity would presently attract such matter towards the planets, where it would replenish water lost in evaporation and in conversion into earth:

> . . . for as the seas are absolutely necessary to the constitution of our earth, that from them, the sun, by its heat, may exhale a sufficient quantity of vapours, which, being gathered together into

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clouds, may drop down in rain, for vegetating the earth, and for the production and nourishment of vegetables; or, being condensed with cold on the tops of mountains (as some philosophers with reason judge), may run down in springs and rivers; so for the conservation of the seas, and fluids of the planets, comets seem to be required, that, from their exhalations and vapours condensed, the wastes of the planetary fluids spent upon vegetation and putrefaction, and converted into dry earth, may be continually supplied and made up; for all vegetables entirely derive their growth from fluids, and afterwards, in great measure, are turned into dry earth by putrefaction; and a sort of slime is always found to settle at the bottom of putrefied fluids; and hence it is that the bulk of the solid earth is continually increased; and the fluids, if they are not supplied from without, must be in a continual decrease, and quite fail at last. I suspect, moreover, that it is chiefly from the comets that spirit comes, which is indeed the smallest but the most subtle and useful part of our air, and so much required to sustain the life of all things with us. (*Principia*, III, XLI, xxi.)

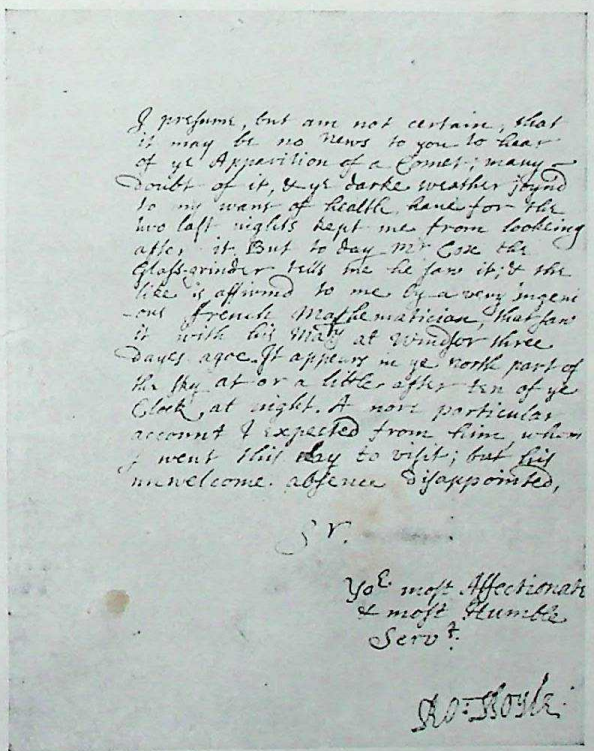
The last sentence links Newton's views with those of BOYLE, HOOKE, and MAYOW on the existence of a vital constituent in the atmosphere, isolated by PRIESTLEY long afterwards and named 'oxygen' by LAVOISIER.

In 1692 Newton drew up a paper entitled *De natura acidorum*, apparently an unfinished composition dealing with chemical affinity. It was published in 1710; but it was in the queries appended to his *Opticks* that Newton approached this problem more closely, and to these famous questions we shall now turn.

According to Newton light was material, and it seemed to him that bodies could be changed into light and light into bodies. Indeed, this appeared to him 'very conformable to the Course of Nature, which seems delighted with Transmutations.' The last clause of Newton's sentence has often been taken from its context as evidence of his being an alchemist! He reminded his readers at this point that water by repeated distillation changed into earth—a scientific 'fact' unrefuted until the work of Lavoisier, long afterwards. A sort of air may be obtained, said Newton, by heating water; and several sorts of air may be obtained when dense bodies, i.e. solids, are rarefied by 'fermentation,' a process which may be reversed so as to make the air thus produced revert by another fermentation to its first state. 'And among such various and strange Transmutations,' he asked, 'why may not Nature change Bodies into Light, and Light into Bodies?'

But chemists will always find most interest in Newton's speculations on the forces concerned in chemical change. He writes:

> Have not the small Particles of Bodies certain Powers, Virtues, or Forces, by which they act at a distance, not only upon the Rays of Light for reflecting, refracting, and inflecting them, but also upon one another for producing a great Part of the Phænomena of Nature? For it's well known, that Bodies act one upon another by the Attractions of Gravity, Magnetism, and Electricity; and these Instances shew the Tenor and Course of Nature, and make it not improbable but that there may be more attractive Powers than these. For Nature is very consonant and conformable to her self.' (*Opticks*, 4th edition, 350-1.)



I presume, but am not certain, that it may be no news to you to hear of ye Apparition of a Comet; many doubt of it, & ye darke weather beyond ye wont of Realle hindred me the two last nights from looking after it. But to day Mr Cox the Glasgrinder tells me he saw it, & the like is affirmed to me by a very ingenious French Mathematician, that saw it with his Maty at Windsor three dayes agoe. It appears in ye north part of the Sky at or a little after ten of ye Clock at night. A more particular account I expected from Lime whom I went this day to visit; but his unwelcome absence disappointed,

Sr

Yor most Affectionate & most Humble Serv.t

R: Boyle.

Part of a letter from Boyle to Newton about the 'Apparition of a Comet,' *a subject in which they both had a chemical interest, since each thought that the 'purpose' of comets was to make good the water lost from our planet by evaporation and by conversion into earth.*

(By courtesy of Air-Commodore Geoffrey Keynes, from a MS. in his possession.)

The deliquescence of 'salt of tartar' (potassium carbonate) Newton ascribed to an attraction between its particles and those of water vapour in the air, while salts that did not deliquesce lacked such attraction; the quantitative limit to the amount of water taken up showed that the attractive force of the salt had been 'satiated.' The development of heat on the mixing of oil of vitriol and water argued a great motion and a violent coalescence of the particles of these liquors. The action of 'spirit of vitriol' on salt and on

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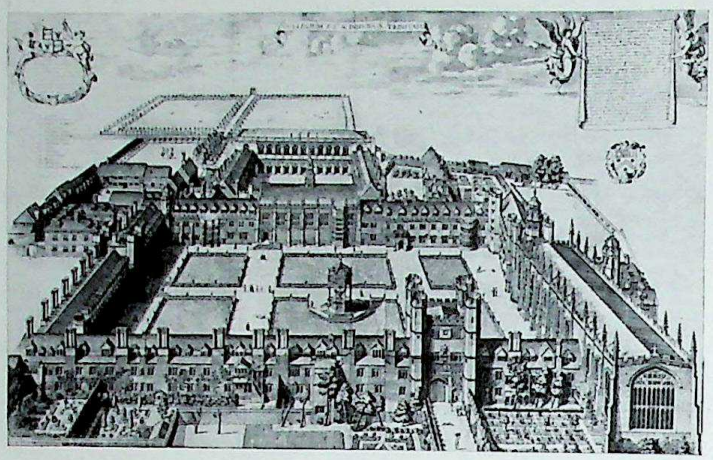
saltpetre, whereby the 'spirits' of these salts ('spirit of salt' and 'spirit of nitre') were produced, while the acid part of the 'spirit of vitriol' remained behind, suggested 'that the fix'd Alcaly of the Salt attracts the acid Spirit of the Vitriol more strongly than its own Spirit, and not being able to hold them both, lets go its own.' The strengths of these attractions between various substances varied, and so the vigour of chemical change ranged from slow ebullition and gentle heat to violent explosion and the heat of fire and flame.



Trinity College, Cambridge, c. 1690.

(*From David Loggan's* Cantabrigia Illustrata, *by courtesy of the Trustees of the British Museum.*)

In precipitations of acid solutions of the metals by means of alkalis, it appeared that the acid particles were attracted more strongly by the alkali than by the metal, and so they went from the metal to the alkali. A similar explanation suggests itself for the deposition of copper from an acid solution of that metal by means of iron. This last example and its explanation remind us that Newton had mentioned it to Aston in 1669 as worthy of his inquiry; what it also suggests is that it can hardly be regarded as evidence for Newton's devotion to alchemy.

It is clear that Newton was greatly interested in the problem of chemical attractions and forces. He considered that the particles of a salt in solution diffused evenly through the solvent as though they were moved from one another by a repulsive force, or, at least, that they attracted the water more strongly than one another. Yet, on evaporation of the solution, these same particles concreted in regular figures, which seemed to argue that before this concretion they were arranged in the solvent 'at equal distances in rank and file' under the action of 'some Power which at equal distances is equal, at unequal distances unequal.' He followed this to its logical conclusion of polarity in the particles:

> For by such a Power they will range themselves uniformly, and without it they will float irregularly, and come together as irregularly. And since the Particles of Island-Crystal act all the same way upon the Rays of Light for causing the unusual Formation of this Crystal, the Particles not only ranged themselves in rank and file for concreting in regular Figures, but also by some kind of polar Virtue turned their homogeneal Sides the same way? (*Ibid.*, 363.)

Newton was prepared to infer that the cohesion of the particles of solids was due to an attractive force, which was very strong in immediate contact, produced chemical action at short distances, and did not extend far from the particles.

Since all bodies appeared to be composed of hard impenetrable particles, some attractive force was necessary for cohesion. The concretion of particle upon particle produced larger particles with weaker powers of attraction, and so on, until the particles became of those dimensions at which chemical changes occurred and where, by further cohesion, bodies of sensible magnitude were produced. There was likewise a repulsive force, as already noted. So, said Newton:

> Nature will be very conformable to her self and very simple, performing all the great Motions of the heavenly Bodies by the Attraction of Gravity which intercedes those Bodies, and almost all the small ones of their Particles by some other attractive and repelling Powers which intercede the Particles. (*Ibid.*, 372.)

But he, who had achieved the unique triumph of formulating the mathematical law of gravitational attraction, was unable to wrest from Nature the laws of chemical attraction and to arrive at any corresponding simple numerical relationship. The problem is indeed one of far greater difficulty, since the attraction varies with the chemical nature of every reactant instead of with mere mass. Even today it would be bold to claim that progress on this problem reveals anything remarkably satisfying. Yet it might well be that here was the great object of Newton's chemical speculations and researches, and that here in the microcosm of chemistry he sought to parallel his discoveries in the macrocosm of mechanics.

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Evolution of the chemical laboratory

J. R. PARTINGTON

From its nebulous beginnings in ancient alchemy, chemistry slowly assumed coherent form and at length developed into the proud science of the nineteenth and twentieth centuries. The metamorphosis in thought and theory was accompanied, and partly conditioned, by a metamorphosis in laboratory accommodation and equipment. Professor Partington acts as guide on a tour of the chemical laboratory through the ages.

The size and arrangement of a laboratory depend on the kind of apparatus it contains and the nature of the work done in it. For a long time chemical operations were of two main types, metallurgical and pharmaceutical, and the recognition of chemistry as a distinct science came later, largely as a result of the development of chemical analysis early in the seventeenth century.

We may first notice that much chemical apparatus goes back to the first few centuries A.D. The Greek treatises on the 'Divine Art' then composed in Alexandria (a centre of skilled glass-blowing) describe and depict apparatus for calcination, solution, sublimation, and distillation. The distilling flask (*lopas*) is surmounted by a spouted vessel (*ambix*), forming what was afterwards called the *alembic*. The *kerotakis* was a small charcoal brazier heating a metal plate used for sublimation. Quite small weights of materials are specified. Much of this apparatus, we are told, was devised by MARIA, fragments of whose writings were preserved by ZOSIMOS OF PANOPOLIS (third century).

The Muslim chemists, such as JABIR (eighth century) and RAZI (ninth and tenth centuries), used much the same apparatus. They also had the *athanor*, a tower furnace burning for long periods without attention and giving an equable temperature.

Alchemy came to Europe about A.D. 1200, and in the next few centuries the alchemist became familiar in literature and art; the alchemical laboratory, with its lofty and gloomy interior, forms the subject of many paintings of the Dutch School. In these, the apparatus is faithfully represented but often regrouped for artistic effect. The picture by OSTADE shows fireplace and bellows, in the foreground the alembic resting in a large pot, the crucibles, chafing-dishes, pestle and mortar, and jars.

In some such interior the alchemist pursued his elusive quest. ANDREAS LIBAVIUS (1540–1616), the author of the first textbook of chemistry, gives in 1606 drawings and plans of a 'Chemical House,' or self-contained laboratory, an ideal place whose hospitable interior was to include a main laboratory, a store-room, a room for crystallizing and freezing, a room for sand-baths and water-baths, a fuel store, and a wine cellar!

Such a goodly place was not to materialize for many a long year, and the laboratory usually consisted of one or two large rooms with stone floors to allow of the use of several furnaces built round the walls and worked by draught or bellows, which we find in place until the middle of the nineteenth century. The alembic in its later development is surmounted by a spiral condenser serving as a crude rectifying column. A laboratory of this kind in the University of Utrecht is shown by BARCHUSEN (1718). The balance is used in the same room and is here shown as hand-scales without a cover, although a balance in a glass case appears in much earlier pictures.

More commodious is the attractive laboratory shown by LEWIS (1763). Various kinds of furnaces are depicted, one surmounted by a sand-bath and alembic. A glass-blower's table with bellows is available, and in the large window-space are a barometer and two balances in glass cases. On a shelf is an early frictional electrical machine. This is the working room of a professional chemist.

In the laboratory of JOSEPH PRIESTLEY (1733–1804) we see a room adapted to experiments on gases. The fireplace and candle serve

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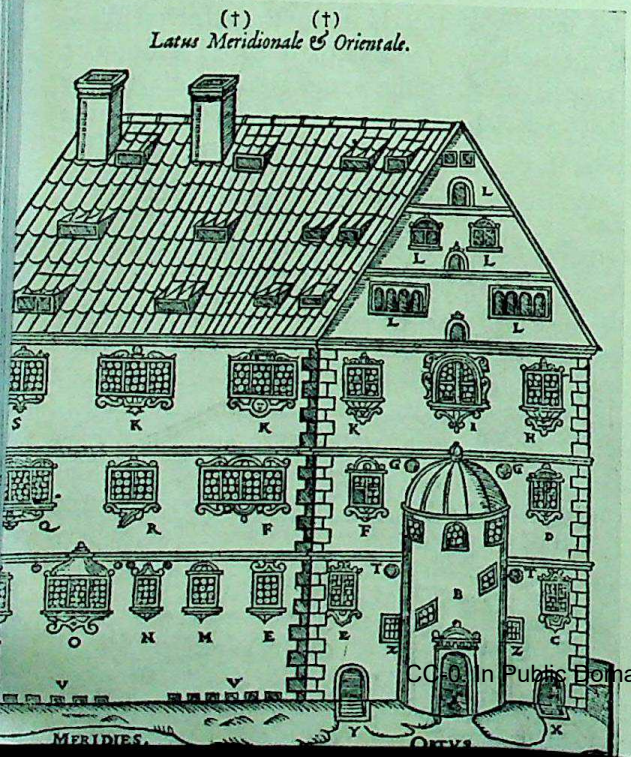
FIGURE 1 – *The Alchemi*
By Ostade. (National Gallery.)

2 – '*Chemical House.*'
vius, *Commentariorum Alchymiae*, 1606.



instead of furnaces, the mercury pneumatic apparatus hangs from two large nails callously driven into the mantelpiece, and the elegant round table supports a piece of apparatus like that with which CAVENDISH was later to synthesize nitric acid from the air and obtain the first bubble of argon.

LAVOISIER (1743–94) used elaborate and costly apparatus: in a drawing by MME LAVOISIER, who is shown seated on the right, we see an experiment on respiration made shortly before his death. Two large pneumatic troughs, one filled with mercury, may be observed. Furnaces and adjuncts are missing, and much of Lavoisier's work was carried out without them. The Argand oil lamp was now coming into use and it was possible to use much smaller apparatus.

The picture of the laboratory at the Royal

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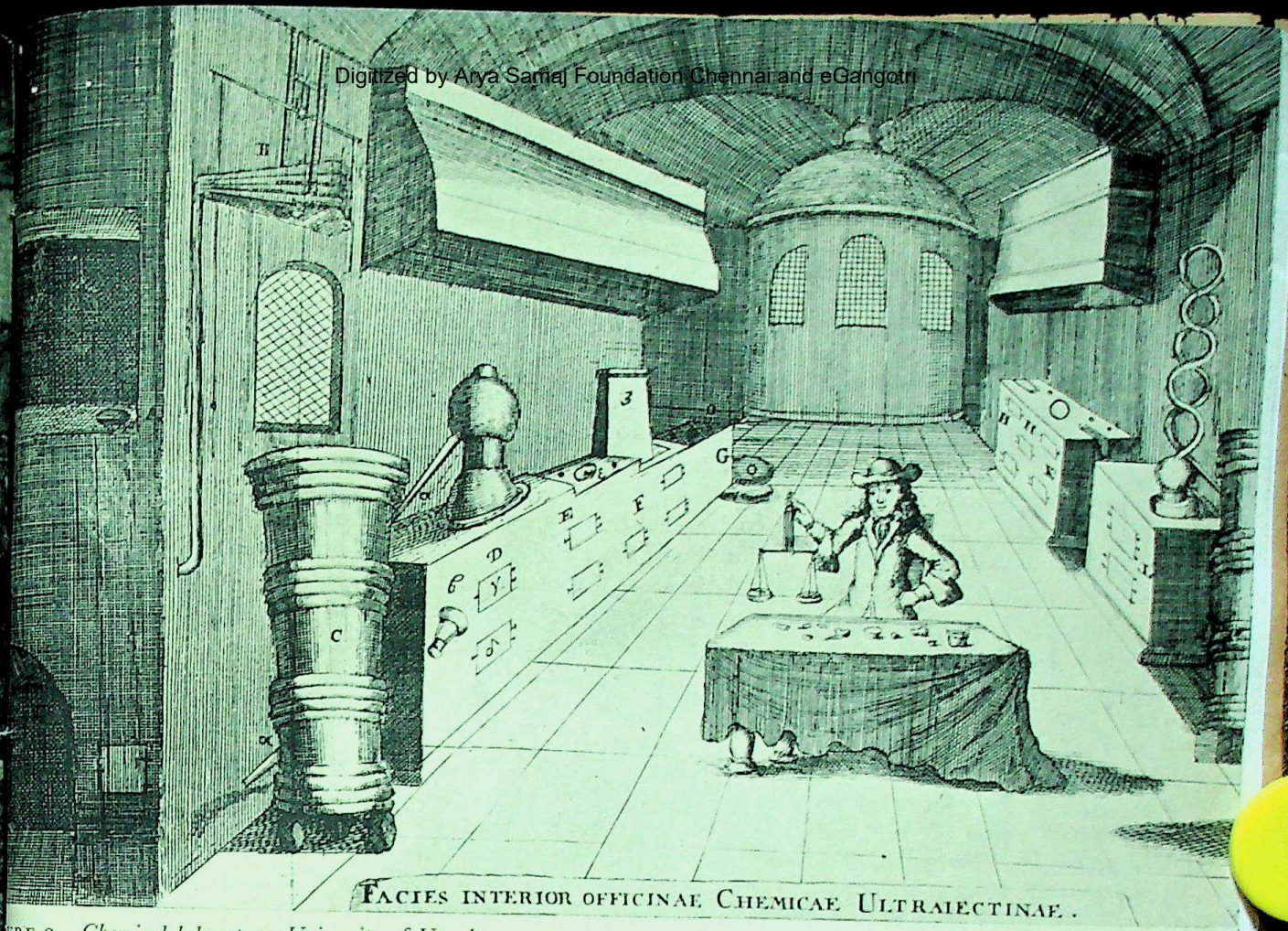
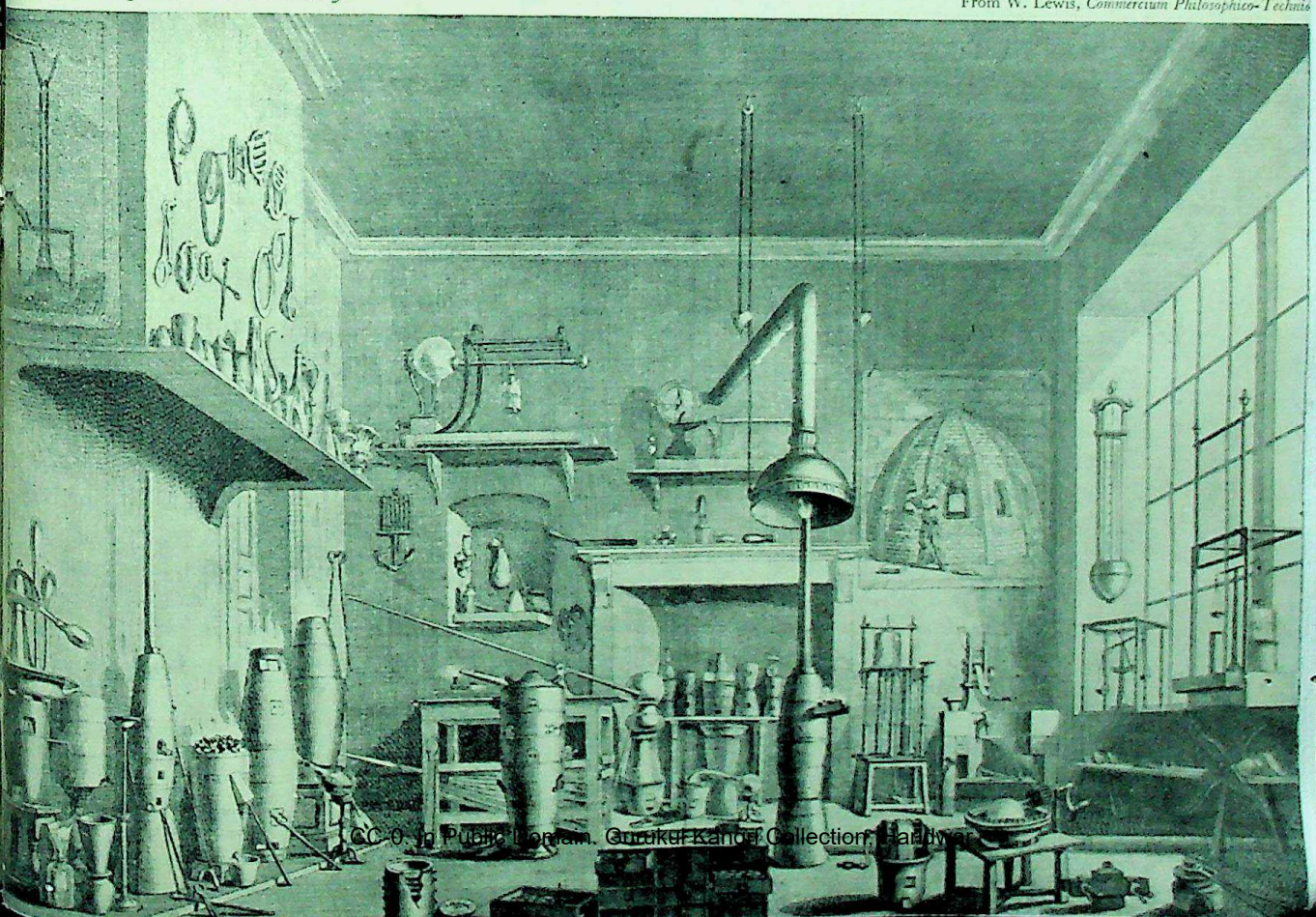


URE 3 – *Chemical laboratory, University of Utrecht.* From Barchusen, *Elementa Chem*

URE 4 – *Large chemical laboratory.* From W. Lewis, *Commercium Philosophico-Technic*



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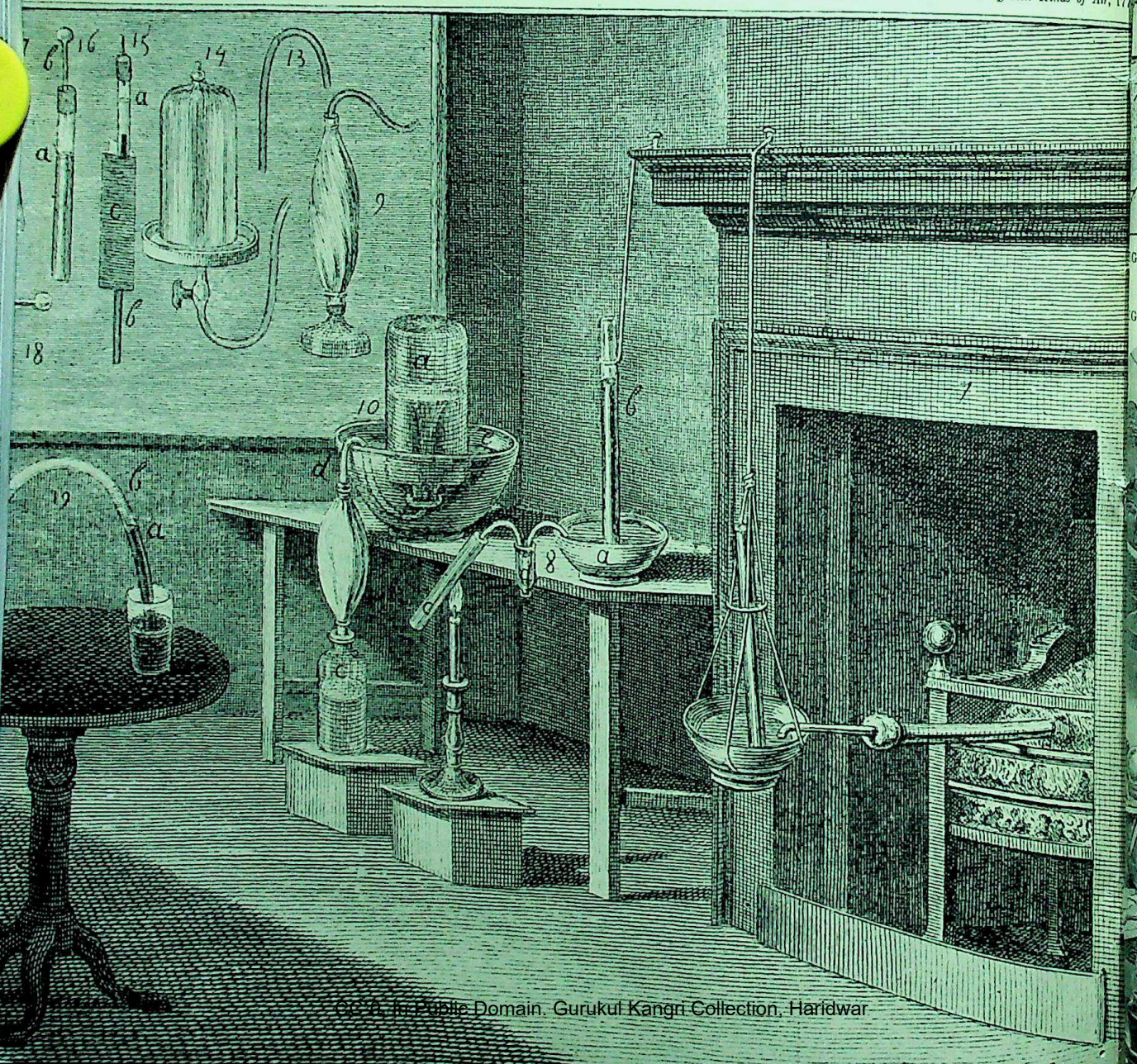
Institution about 1840 shows a large fixed furnace with a sand-bath top, the portable furnaces standing on a shelf, the bellows, and (on the left) an alembic. On the right is a cylinder frictional electrical machine. The floor need no longer be made of stone or brick, but can now be of wood.

The teaching laboratory of LIEBIG at Giessen in 1842 was a place more familiar to a modern chemist than any which have gone before. Heating is still by charcoal; this was fanned and threw off a fine dust which covered everything in the laboratory. The Argand spirit lamp, used for smaller operations, is seen on the bench on the left.

By this time many laboratories used coal-gas. In 1853 the Bunsen burner appeared, and this and its near relation the ring burner still hold their place in the modern laboratory. In this the glass apparatus is still very like that of the earliest period, and an unbroken continuity of development can be traced in the laboratories here illustrated.

The twentieth century research laboratory unites complexity and convenience of resources with chaste severity of design. Water, gas, electricity, steam, and compressed air are unobtrusively but immediately available. The alchemist's untidy miscellany of phials is replaced by orderly rows of stoppered jars and bottles. Fume-cupboards obviate contamination of the atmosphere, and there is certainly no reason why chemists should resemble PARACELSUS's ideal adept, who wore leathern dress and apron and was dirty and sooty like a smith.

5 – *Priestley's laboratory.* From *Experiments and Observations on Different Kinds of Air*, 177



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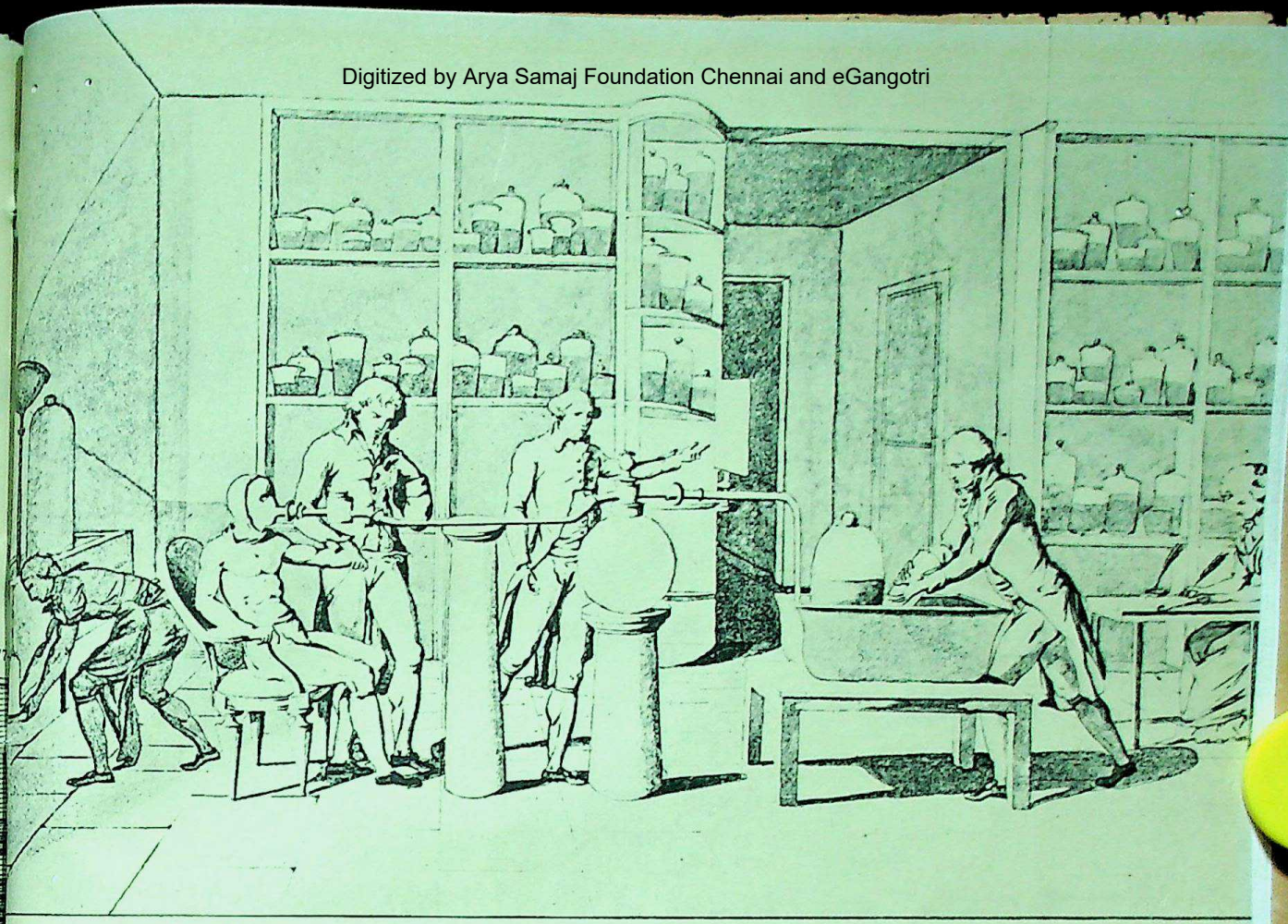
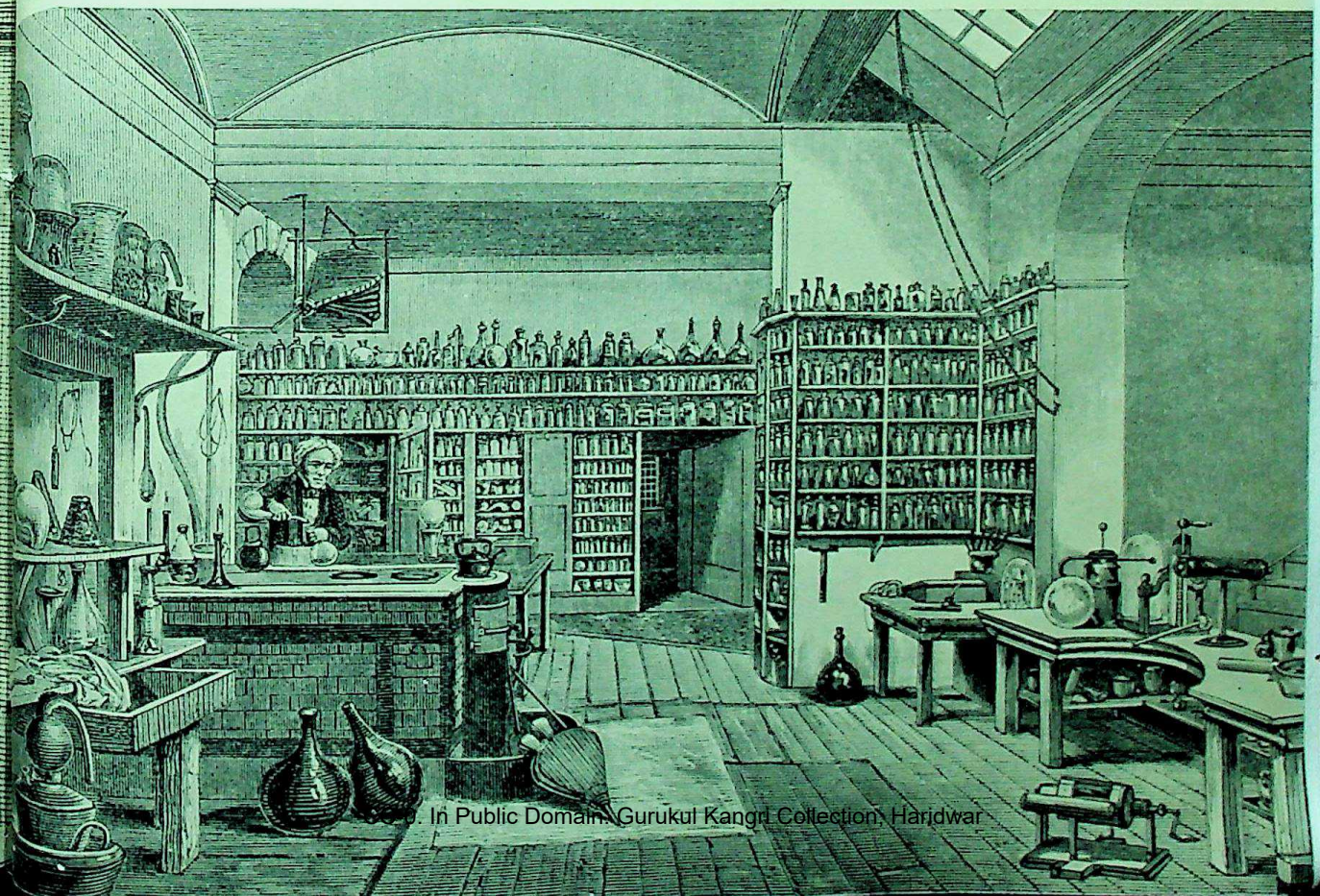


GURE 6 – *Lavoisier's laboratory.* From Grimaux, *L*

GURE 7 – *Royal Institution laboratory.* From Bence-Jones, *Life and Letters of F*



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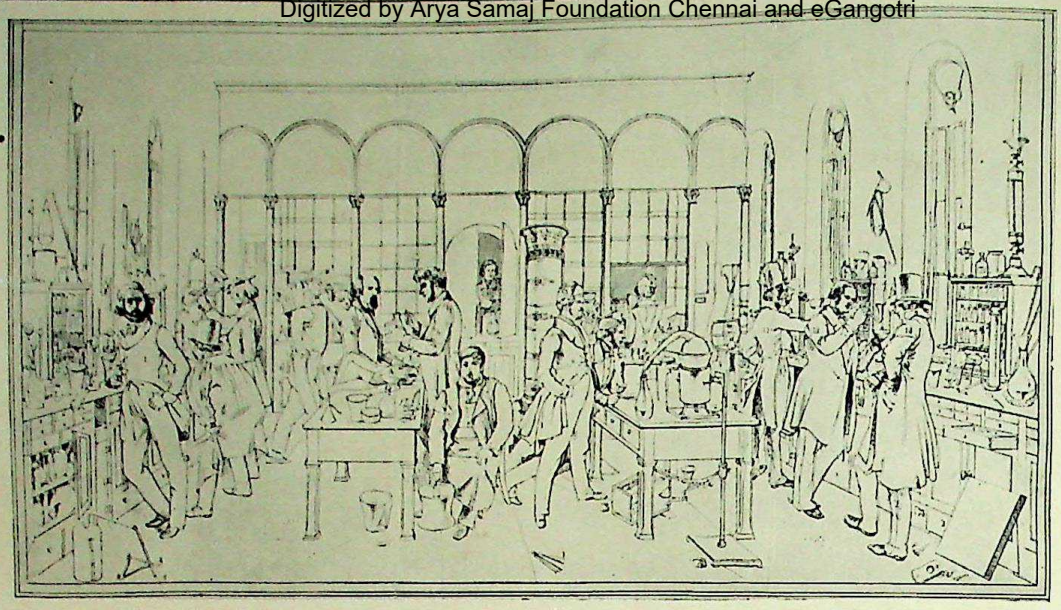
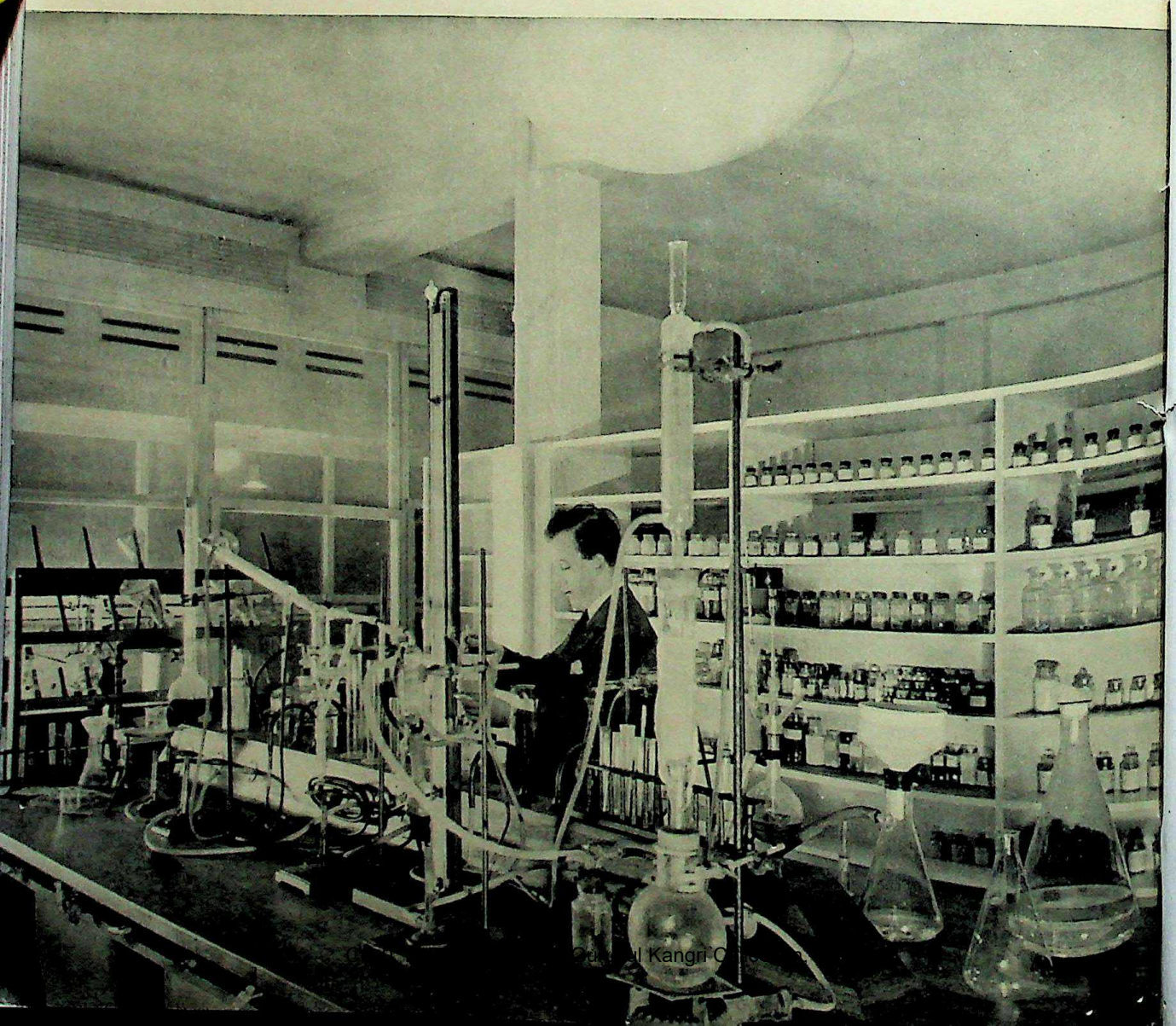


FIGURE 8 – *Liebig's laboratory at Giessen.* From a drawing by Trautschold, 1842.

– *Typical modern research laboratory.*



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The photographic plate in nuclear physics

C. F. POWELL

The structure and behaviour of atomic nuclei continually offer new problems to tax the genius of physicists. Many of these problems involve the collection and recording of large numbers of quantitative data, processes which are liable to be both laborious and lengthy. Dr Powell describes methods of detecting charged particles, of determining their energy, and of mapping their distribution after scattering, much more economical of time and material than those hitherto employed.

(1) THE PHOTOGRAPHIC PLATE AS A DETECTOR OF CHARGED PARTICLES

The development of our knowledge of atomic nuclei depends on the solution of two main technical problems: the production of fast charged particles with which to bombard the nuclei, and the development of methods for the detection of the particles arising as products of the bombardment. A modern design of what is perhaps the most important instrument for the production of bombarding particles of great energy, the cyclotron, has already been described in the pages of ENDEAVOUR (Vol. I, pp. 40 and 41). The purpose of this article is to describe briefly some of the recent developments in the application of an old method of detecting the products of nuclear disintegrations, based on the use of the half-tone photographic emulsion.

For many years it has been known that if α-particles impinge upon a suitable fine-grain photographic emulsion the tracks of the particles, after development, are represented by a linear succession of developed grains. As an example, figure 1 shows a microphotograph of the tracks produced by the α-particles from uranium. The tracks shown in figure 1 are less precise than those obtained in WILSON expansion-chamber photographs, and for many years it was considered that the uncertainties in the lengths of the tracks, i.e. in the range of the particles, was so great that the usefulness of the method was seriously restricted. Several writers, notably BLAU and WILKINS, made important applications of the method for the detection of the heavy particles, protons, etc., which are present in the cosmic rays. For modern work it is necessary, however, not merely to record a particle but also to be able to measure its energy, and the easiest way of doing this is to measure its range in a suitable medium. A well-established relation between the range and the energy of a particle then enables the initial energy to be deduced. With large uncertainties in the range there are correspondingly large uncertainties in the energy.

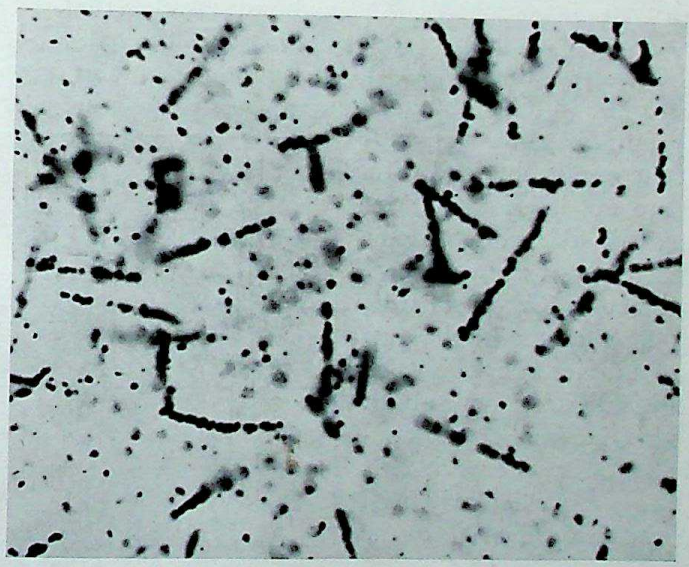

FIGURE 1 – *α-particles from uranium. There are two groups present, of mean range 2·65 and 3·2 cm. of air. Microphotograph with 3 mm., × 50 apochromatic oil-immersion objective, with × 12 eyepiece. The small depth of focus prevents more than a few grains of any track not parallel to the focal plane of the objective from being in focus at the same time. This restricted depth of focus enables the angle at which a track 'dips' into the emulsion to be determined.*

The advantages offered by the photographic method if it could be made precise were so great that it seemed worth while to re-examine it using the best available plates and good modern microscope technique. The earlier work with the method had been

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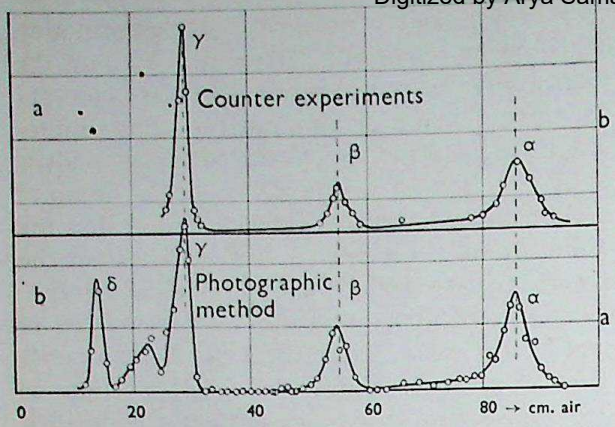

FIGURE 2 – *Range distribution of the protons from the disintegration of boron with* 600 *kv. deuterons. Curve* a *results by counter methods; curve* b *by photographic method. The proton group of greatest range corresponds to the reaction* $B^{10}_{5} + H^{2}_{1} \rightarrow B^{11}_{5} + H^{1}_{1}$, *the* B^{11}_{5} *being left in the ground state. The two groups of lower energy correspond to the* B^{11}_{5} *being left in one or other of the first two excited states.*

carried out with weak radio-active sources, so that the number of tracks per unit area of the emulsion was small and the microscopic examination of the plates very tedious. The development of artificial sources of bombarding particles of much greater intensity provided more favourable conditions for such a test. Half-tone emulsions were therefore exposed to the disintegration protons emitted when boron is bombarded by deuterons with an energy of 600 kv. from the Bristol high-tension generator. The distribution in length of the resulting tracks is shown in figure 2, where the results obtained by counter methods are reproduced for comparison. It will be seen that the results obtained with the photographic plate are not inferior to those given by the counter methods. Measurements of the ranges of the α-particles from uranium and thorium were also in satisfactory agreement with the results obtained by other methods, the two groups of α-particles from uranium of range 2·65 and 3·2 cm. (in air) being satisfactorily resolved. The reliability of the method having been demonstrated, it was applied to a number of experiments for which it appeared to be particularly well adapted, the first being the determination of the energy of fast neutrons.

(2) DETERMINATION OF THE ENERGY OF FAST NEUTRONS

Since a neutron carries no charge, it passes through matter without ionizing it and thus cannot be detected as easily as a charged particle. The most accurate method hitherto available for the determination of the energy of fast neutrons has been to pass them through an expansion-chamber filled with hydrogen. A small proportion of the neutrons passing through the chamber makes collisions with the hydrogen nuclei. If the hydrogen nucleus, i.e. the proton, is projected at an angle of less than 5° with the original direction of the neutron hitting it, it takes up more than 99 per cent. of the energy of the neutron. The proton-tracks thus produced in the gas are made visible by the expansion and are photographed in the usual manner. The impact is essentially similar to the collision of equal elastic spheres, for the neutron and proton are of almost equal mass. By measuring the range of the knocked-on protons the distribution in energy of the incident neutrons can thus be deduced.

This method has the disadvantage that it is very laborious, for thousands of photographs have to be taken if the distribution in energy of the neutrons is at all complex.

For such experiments the photographic plate method has the advantage that, unlike the expansion-chamber, with which a photograph is taken once every minute or two, the plate is continuously sensitive. It contains combined hydrogen in the gelatine of the emulsion, and neutrons passing through it thus project protons just as in the hydrogen-filled expansion-chamber. The proton-tracks are made visible by development, and by measuring the range in the gelatine of all protons projected at an angle of less than 5° with the direction of the neutron stream, the energy-distribution of the

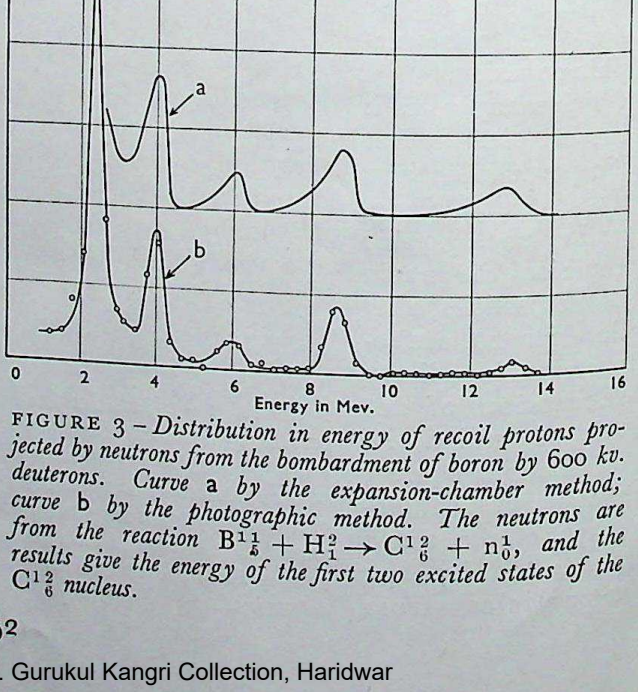

FIGURE 3 – *Distribution in energy of recoil protons projected by neutrons from the bombardment of boron by* 600 *kv. deuterons. Curve* a *by the expansion-chamber method; curve* b *by the photographic method. The neutrons are from the reaction* $B^{11}_{5} + H^{2}_{1} \rightarrow C^{12}_{6} + n^{1}_{0}$, *and the results give the energy of the first two excited states of the* C^{12}_{6} *nucleus.*

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incident neutrons can be deduced just as with the expansion-chamber. With the photographic plate, however, experimental material is obtained in an exposure of some minutes which would require several months with the expansion-chamber. In experiments employing the cyclotron this economy of time during which the machine is occupied is an advantage of great importance.

Figure 3 shows the distribution in energy of the neutrons from boron under bombardment with 600 kv. deuterons, as deduced by the photographic method, the corresponding results obtained by BONNER and BRUBAKER, using the expansion-chamber, being reproduced for comparison. The measurements by the photographic method were obtained in the microscopic examination of 3 sq. cm. of an Ilford half-tone plate with an emulsion 50 μ thick. It will be seen that in this case also the resolving power attained with the photographic method is not inferior to that attained with the best alternative method available. The method has been applied to the neutrons from other of the light elements, such as deuterium, beryllium, lithium, and fluorine, under bombardment with 600 kv. deuterons, and to the same problem using the 7·4 Mev. deuteron[1] beam produced by the Liverpool cyclotron.

(3) EXCITED STATES IN NUCLEI

The experiments of the type described in the previous paragraph give us important information about the nuclei involved in the various reactions. Thus the reaction leading to the emission of protons when boron is bombarded with deuterons (*see figure* 2) is written

$$B^{10}_{5} + H^{2}_{1} \rightarrow B^{11}_{5} + H^{1}_{1}$$

Boron isotope of mass number 10 + *Deuteron* → *Boron isotope of mass number 11* + *Proton*

The masses of the various nuclei involved in this reaction have been determined by the mass-spectrograph, and if the appropriate values are substituted it is found that the total mass on the left-hand side exceeds that on the right-hand side of the equation. By the well-known principle of the equivalence of mass and energy the disappearance of an amount of matter Δm grams must be compensated by the appearance of an mount of energy ΔE ergs where $\Delta E = c^2 \Delta m$, c being the velocity of light in centimetres per second. This kinetic energy appears in the motion of the nuclei produced. Taking into account the kinetic energy supplied by the incident deuteron, the energy—and hence the range—of the disintegration protons can be calculated. The result is in agreement with that observed for the group of protons of longest range in figure 2, and thus the disintegration experiments give a check on the masses as determined by the mass-spectograph. Alternatively, if the mass of one of the nuclei in such a reaction is unknown, it can be computed from the energy released in the reaction as determined from such disintegration experiments.

We can account for the proton groups of lower energy in figure 2 if we assume that, just as with the electronic structure of the atom, so the energy of the assembly of protons and neutrons which constitute any nucleus can have only certain discrete values. The state of lowest energy is termed the 'ground' state, and states of higher energy are described as 'excited' states. The groups of protons of lower energy in figure 2 correspond to the product boron nucleus, B^{11}_{5}, having been left in one or another of various excited states so that correspondingly less energy is available to appear in the form of motion of the product nuclei. From the observed values of the energies of the proton groups we can calculate the energies of the various excited states of B^{11}_{5}.

In a similar way the reaction giving rise to the neutron groups shown in figure 3 is written

$$B^{11}_{5} + H^{2}_{1} \rightarrow C^{12}_{6} + n^{1}_{0}$$

Boron 11 + *Deuteron* → *Carbon* 12 + *Neutron*

and the energy of the various groups of neutrons enables us to calculate the values of the energy of the excited states of C^{12}_{6}.

Experiments of this type thus lead us to the conception of excited states in nuclei, and a great deal of information on the energy of the excited states of various nuclei has now been accumulated. Such studies may be included under the general title of nuclear energetics and are of great importance; but for the development of the theory of the nucleus they must be supplemented by others of a different type.

(4) SCATTERING EXPERIMENTS WITH ELEMENTARY PARTICLES

We regard the nucleus as built up of protons and neutrons. At relatively large distances from the nucleus the field of force is an inverse square field corresponding to the positive charge on it, but, since the nuclei are stable structures, other

[1] It is convenient to measure the energy of nuclear particles not in ergs, but as a ratio to the energy that an electron acquires in falling through a difference of potential of 1 volt. This unit is the electron volt, commonly designated 1 ev. 1 Mev. = 10^6 ev.

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specifically nuclear forces of a new type must come into play at short distances. It is therefore a matter of great importance to determine the character of the forces between these elementary particles—between two protons and between a neutron and a proton—when they are very close to one another. Here the scattering method remains the most valuable, and the photographic plate has been applied to the study of the scattering of fast neutrons by protons. For this purpose it is necessary to determine the distribution in angle of the protons scattered by a homogeneous group of neutrons of high energy. Such homogeneous groups are produced, as we have already seen, by the bombardment of boron by deuterons. Using the photographic method, it has been found

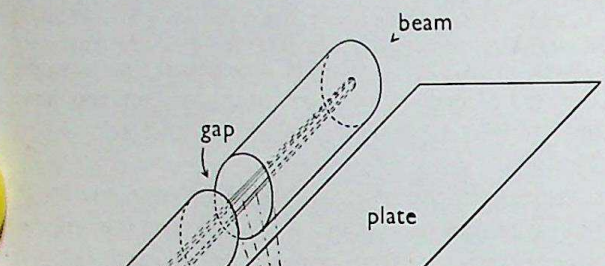

FIGURE 4 – *Schematic representation of the method for the investigation of the scattering of high-energy protons and deuterons from the cyclotron. Width of gap greatly exaggerated.*

possible to determine the spatial orientation of a track in the emulsion with an accuracy of the order of 1°, and to study the intensity of the projected protons as a function of the angle of scattering.

The results of scattering experiments are most conveniently analysed by referring the observed scattered intensity to a co-ordinate system at rest with respect to the centre of mass of the colliding particles. When this is done for the observed scattering of neutrons by protons it is found that the scattering is isotropic about the centre of mass, i.e. the probability of the neutron being scattered into any small solid angle δ_ω is the same in all directions, independent of the value of the angle of scattering. This result is analogous to the scattering of light by small particles when the wave-length of the light is larger than the diameter of the particles. We are presented in this case with an aspect of the particle-wave duality of matter with which we have been made familiar in recent years by the interference effects shown by electron beams and by the development of the electron microscope. For the description of the behaviour of an electron or an atom we have to attribute wavelike characteristics to them, the wave-length λ being given by the relation $\lambda = h/mv$ where m is the mass of the particle, v its velocity and h PLANCK's constant. The isotropic scattering of neutrons by protons is then accounted for, if the range of action of the neutron-proton forces is small compared with $\lambda/2\pi$ for the interacting particles. Similar isotropic scattering has also been observed in the case of the scattering of 8 Mev. protons by protons.

(5) SCATTERING EXPERIMENTS WITH PROTONS AND DEUTERONS FROM THE CYCLOTRON

We have just seen that, with neutron sources of the energy at present available, we cannot obtain any detailed information about the neutron-proton forces. We require primary particles of higher energy and correspondingly shorter wave-length, and it should be possible to employ the higher-energy protons now available for experiments on proton-proton scattering. We can, however, as an alternative, use incident particles of the same wave-length and scatter them from larger nuclei with a more extended field of force.

For such investigations, experiments with the high-energy charged particles produced by the cyclotron are particularly important. A beam of particles from the cyclotron, of small angular spread, is defined by a system of stops. This beam is scattered by a thin foil or by the atoms of a gas, and the intensity of the scattered beam at any angle is determined. It is difficult to use the expansion-chamber for such work, and counting-methods have the disadvantage that the intensity at each angle has to be determined separately. Especially in experiments with deuterons, where the elastically scattered particles are generally accompanied by a very complex distribution of disintegration particles, a complete investigation by counting-methods would occupy the cyclotron over a very extended period. The photographic method has the great advantage that the scattered intensity at all angles can be determined from a single exposure lasting for a few minutes, and a great wealth of experimental material is thus obtained as a permanent record in the emulsion. Most of this material is normally

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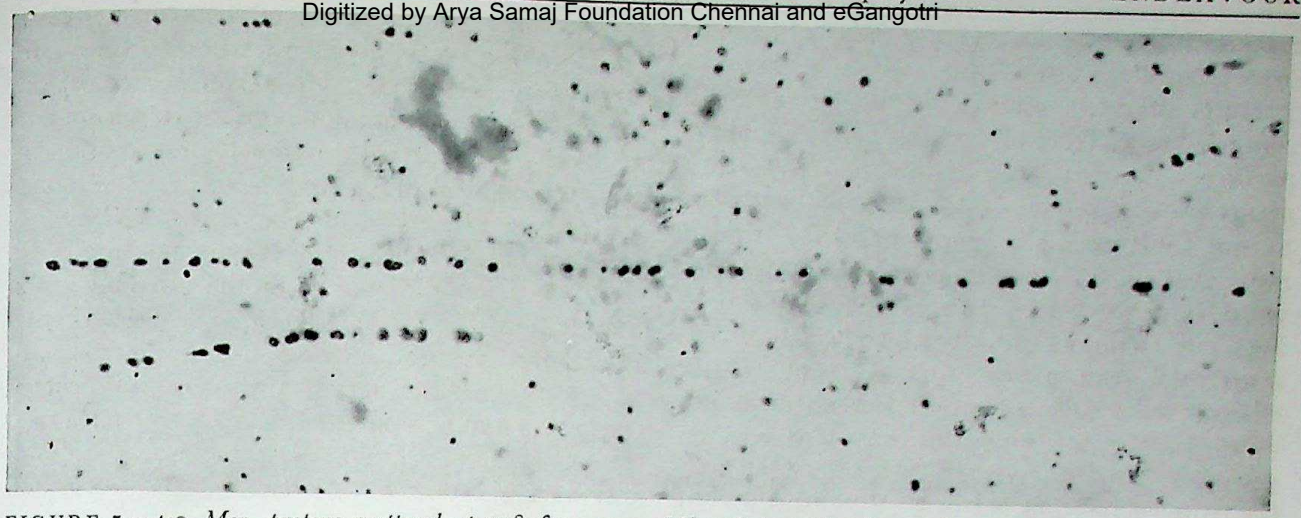

FIGURE 5 – 4·0 *Mev. protons scattered at* 30° *from neon. Microphotograph taken under same conditions as figure* 1. *The long track is an elastically scattered proton. The short one is an inelastically scattered proton, the* Ne^{20}_{10} *nucleus having been left in its first excited state at* 1·5 *Mev. in the scattering process. The tracks enter the plate at a glancing angle of about* 3°, *and in taking the photograph the plate has been tilted on the stage in order to bring the long track into focus throughout its length. Note the smaller grain density in the proton-tracks as compared with the* α*-tracks. The longest range proton so far found is a cosmic ray proton which had a range of* 14 *metres of air, roughly* 100 *times the length of the long track in the figure. The grain density of this track differs very little from that in the figure.*

not employed, but any part of the scattered distribution can be examined in detail if the preliminary measurements make it appear desirable.

Two methods of using the photographic plate in such experiments have been employed. The first, due to Wilkins, is to scatter the beam from thin foils and to record the scattered particles by a large number of separate plates; these are arranged at equal distances around the foil and are so disposed that the scattered particles make a small glancing angle at the surfaces of the emulsion. The second method, which has been developed by DR A. N. MAY and the writer in collaboration with PROFESSOR J. CHADWICK, is to make the primary beam pass down the axis of a tube provided with an interruption. The whole 'camera' is filled with the scattering gas, and particles scattered from the beam by the gas pass through the gap to enter the single photographic plate at a small glancing angle. The flat plate has its surface parallel to the axis of the primary beam and below it, and a single plate contains information on the scattering in the continuous range of angles from 10° to 170°. The essential features of the apparatus are shown in figure 4.

Using the above methods, experiments have been made on the scattering of protons by the light elements. With his camera Wilkins studied the scattering of 6·0 Mev. protons from magnesium and aluminium foils. At all angles of scattering he found two groups of protons in the scattered beam: a group corresponding to the elastic scattering of the incident protons by the nuclei of the foil, and a second group corresponding to inelastic scattering in which the incident proton excites the struck nucleus and thus leaves the collision with correspondingly reduced energy. Similar results were obtained by the second method in experiments with neon, and figure 5 shows a microphotograph of tracks scattered from this element. The long track is produced

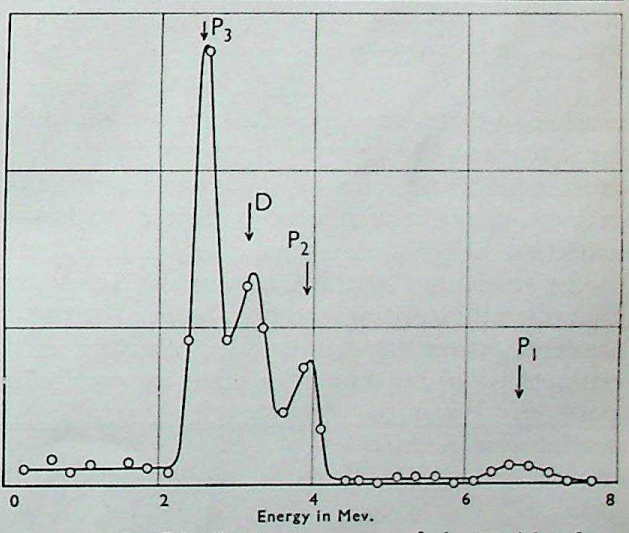

FIGURE 6 – *Distribution in energy of the particles from carbon bombarded with* 7·0 *Mev. deuterons, emitted at* 90°. *The groups marked* P_1, P_2, *etc., are protons from the reaction* $C^{13}_6 + H^2_1 \rightarrow C^{13}_6 + H^1_1$. *The peak marked* D *is due to elastically scattered deuterons. The energy distribution is calculated from the observed distribution in range, assuming that all the particles are protons.*

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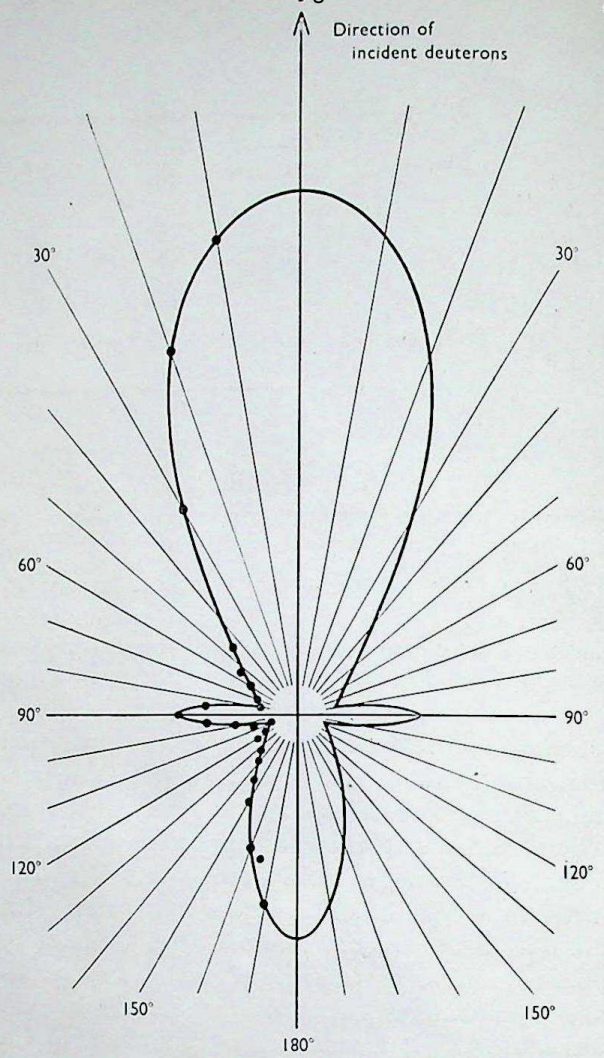

FIGURE 7 – *Distribution in angle of the intensity of the protons from the disintegration of carbon by 7·0 Mev. deuterons. Reaction* $C^{12}_6 + H^2_1 \rightarrow C^{13}_6 + H^1_1$, *the* C^{13}_6 *nucleus being left in the ground state. The protons from the disintegration of nitrogen and oxygen by deuterons also show striking anomalies.*

by a 4 Mev. proton scattered elastically from a neon nucleus, and the short track by a proton which in the scattering process has raised a neon nucleus to its first excited state at 1·5 Mev. The distribution with angle of the intensity of the elastically scattered protons has been examined by the photographic method, using twelve different gases. The observed distributions show large departures from those to be expected if the only force between the colliding particles were the Coulomb repulsion due to the charges on the nuclei, but more striking evidence of interference effects is provided by similar experiments with deuterons.

In experiments with 7·0 Mev. deuterons the particles emitted at any angle include, in addition to the elastically scattered deuterons, protons and α-particles arising from disintegration processes. As an example, figure 6 shows the distribution of the particles emitted from carbon at an angle of 90°. For convenience in representation the distribution in range has been transformed to an energy scale on which all the particles are assumed to be protons. The weak group of particles of highest energy consists of protons from the reaction $C^{12}_6 + H^2_1 \rightarrow C^{13}_6 + H^1_1$, the C^{13} nucleus being left in the ground state. This group of protons is clearly resolved from the other groups at all angles, so that we are able to determine the variation of its intensity with angle over the range from 10–170°.

The result is represented in a polar diagram in figure 7, where it will be observed that the distribution shows marked anomalies, reminiscent of the variation in the intensity of the light scattered by small transparent spheres. The protons arising from the disintegration of oxygen and nitrogen by deuterons of the same energy show even more complex distributions. We are here faced with problems of considerable complexity which present nuclear theory is not yet sufficiently developed to describe, and it will be necessary to investigate the phenomena over a wide range of deuteron energies. This is a problem of the future, and physicists can still share the congratulations which LORD RUTHERFORD frequently extended to his students on the fact that in nuclear physics there are ever new worlds to conquer. It seems clear that the photographic method has a useful part to play in such investigations.

THORPE'S DICTIONARY OF APPLIED CHEMISTRY

A new edition of this invaluable dictionary is now in course of publication, but the death of SIR JOCELYN THORPE has made editorial rearrangement necessary. In order to maintain a balance between the various branches of pure and applied chemistry an editorial board has been formed, comprising PROFESSOR I. M. HEILBRON (*chairman*), DR H. J. EMELEUS, PROFESSOR H. W. MELVILLE, and PROFESSOR A. R. TODD. This board will determine the general editorial policy in conjunction with the publishers (Longmans, Green & Company Limited). DR MARTHA WHITELEY continues as editor, and DR A. J. E. WELCH becomes assistant editor.

The principal modification in the general character of the work will be an increased proportion of articles on physico-chemical subjects. The new edition, of which five volumes have already been published, is to be completed with Vol. VI, now in the press, and eight further volumes. It should be unique as a work of reference for scientific workers in the English-speaking world.

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Fossils in the search for coal

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A. E. TRUEMAN

Rapid and precise identification of coal seams is clearly a matter of great practical importance, especially in a country—such as Great Britain—where coal is the prime mineral resource. Professor Trueman describes how an originally amateur investigation of the fossil shells in the Coal Measures has gradually yielded invaluable criteria for the mining engineer. The results have been applied not only in Britain but in Russia and other countries.

Until a comparatively few years ago, students of applied geology were mainly concerned with mineralogy and rock structures. Palaeontology was of little importance to those engaged in the mining of ore deposits, and was generally regarded as valueless in the working of coal and bedded rocks. In recent years, the importance of the study of fossils for those seeking to apply geology to economic problems has been widely recognized, chiefly on account of the work which has been carried out in connection with oilfield development.

The use of fossils in coalfield exploration has not perhaps attracted so much attention, but the progress of this new application in Britain and some other European countries, and especially lately in Russia, has been very considerable. Since the war began, fossil-collecting has been actively carried out in practically all British coalfields as a basis for an interpretation of the structural factors involved in each area. Greater precision of information regarding the location and identification of the seams means less exploratory work needed to develop them. The value of this type of information has been abundantly proved in the mining developments in several British coalfields during recent years.

The application of palaeontology to coalfield geology is essentially nothing more than an extension of normal stratigraphical methods. Since the days of WILLIAM SMITH, who recognized that rocks of particular ages are characterized by their own peculiar suites of fossils, geologists have demonstrated that greater refinement in the study of palaeontology makes it possible to identify thinner rock groups (representing shorter time-intervals) and to correlate them over wide areas. This 'zoning' of the chief rock formations was greatly advanced during the latter portion of the nineteenth century, but the Carboniferous rocks —although the most valuable economically in Britain—shared in the progress to only a minor degree. There were several reasons for this, some of which are touched on below.

Many of the fossils which are found in the Coal Measure rocks are very familiar, and it is unnecessary to refer to the abundant trunks and roots which are frequently encountered, or to the fern-like leaves which are such striking evidence of Carboniferous vegetation: indeed, the coal seams themselves are made up of the remains of this material. In addition to the plants, there are numerous remains of the Carboniferous fauna to be met with as fossils in the rocks associated with coal seams. Apart from the comparatively rare remains of insects and land animals, and the not infrequent traces of many types of fish, there are many shells to be found in the Coal Measures. Those which are by far the most abundant in many areas may be compared in general character with the freshwater mussels (*Unio* and *Anodonta*) which occur in many rivers and ponds

Naiadites flexuosa. *Notts. coalfield.*

Naiadites flexuosa. *Notts. coalfield.*

Anthracomya warei. *Mansfield Marine Bed, Nottinghamshire.*

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Associated with them are smaller bivalve shells resembling the modern *Sphaerium*, and other more *Mytilus*-like types. These Coal Measure shells are at present referred to four genera, *Carbonicola*, *Anthracomya*, *Anthraconauta* and *Naiadites*, examples of some of which are illustrated. Shells of marine types also occur in the Coal Measures, but are confined to thin beds.

The fundamental work on these shells was carried out in the last decade of the nineteenth century by an English medical man, WHEELTON HIND, who in the course of an active professional life in Staffordshire devoted his leisure to the study of fossil molluscs from the Carboniferous rocks. It may be noted that British geology owes much to the amateur investigator, pursuing the subject in his spare time, but often achieving results which place him among its leading exponents. Hind, like others who have studied the Coal Measure shells, had no connection with the mining industry and no interest in the possible economic value of his investigations: he followed his own inclinations, and his chief stimulus was a desire to know. His well-illustrated monograph, published by the Palaeontographical Society (1894–96), will long form a work of reference for European workers.

Hind confirmed the view that most of the coal-bearing rocks were deposited in fresh water. He also showed the difficulty of classifying the freshwater shells owing to their extreme variability, but demonstrated that their distribution made it possible to recognize in the Coal Measures broad zones in which certain groups were dominant. Closely associated with Hind was another Staffordshire geologist, J. T. STOBBS [1], who was more interested in mining matters and sought to show the usefulness of fossils in mining problems. He paid particular attention to the marine layers, showing that these are few in number and represent short but often widespread incursions of the sea into the freshwater lake or lagoon in which the rocks were laid down. He thus deduced that they form datum planes within the rock sequence from which the position of known seams can be measured. This conclusion, reached in North Staffordshire, has proved of the greatest reliability, and in the development of the concealed coalfield of East Nottinghamshire and Yorkshire the position of one such bed, the Mansfield Marine Bed, has been invaluable in determining the structure of the area and in tracing the chief seams sought in the deeper mining of that area (figure 1).

The use of such criteria did not extend greatly beyond these coalfields of the North Midlands of England. In some coalfields it was considered that fossils were too rare to be of use: in others, inaccurate identifications of shells led to conclusions which were contested, and generally the study of the shells made little progress for a number of years. This state of affairs led to an increased interest in the fossil plants, but at no stage was the investigation carried far enough to afford much information of value to the mining industry. The geology of the Coal Measures, not only in Britain but in most European countries, continued to lack adequate palaeontological foundation until some years later.

Renewed progress in the study of the molluscan fossils dates from less than twenty years ago, when work begun in South Wales culminated in a revived interest in the fossil faunas which has stimulated work in all British coalfields and has widely influenced research in Europe [2]. South Wales was a fortunate area for the initiation of these studies, for especially in the west, near Swansea, the Coal Measures are thick, fully developed, and fossiliferous throughout. In more northerly coalfields, when the rocks are fully represented the upper part is often almost devoid of fossils and of coal seams (as shown in figure 2), while in other areas the sequence is incomplete. It thus proved possible to divide the Coal Measures into a series of zones, each of which has now been traced, with minor modifications, into the coalfields of many countries. In their main features the same zones have been recognized as far afield as the Donetz basin.

The wide occurrence of the same types of shells in different areas, apparently at the same time, raises some interesting questions. There has long been a tendency to suppose that these freshwater types lived in lagoons more or less coincident with the present coalfield boundaries. It had been supposed that the faunas of the lagoons might show individual peculiarities, and it is therefore rather surprising to find such remarkable similarities in the succession of faunas in what were

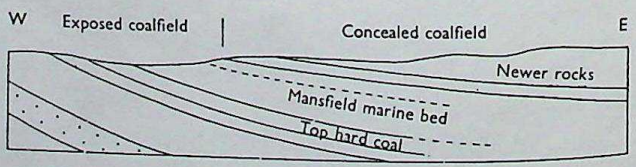

FIGURE 1 – *Diagrammatic section across the exposed coalfield of Nottinghamshire/Yorkshire and its concealed easterly extension, illustrating the use of the Mansfield Bed as a guide to the position of the underlying coals.*

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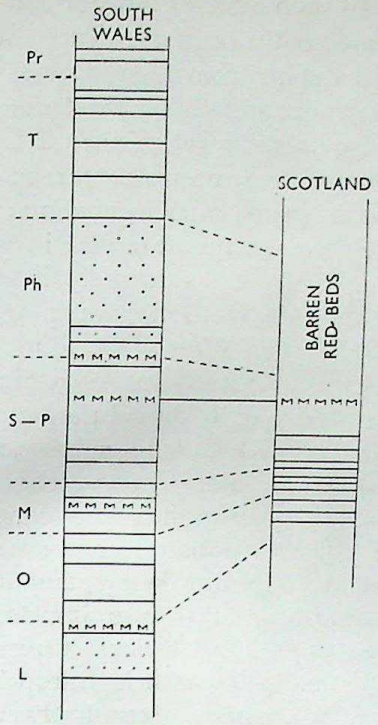

FIGURE 2 – *Diagrammatic sections (not to scale) of the Coal Measures of South Wales and Scotland. Chief coal seams indicated by horizontal lines in the sections. Letters on the left are index letters of zonal terms;* MMM *show marine bands.*

formerly regarded as different and separate basins of deposition. These similarities have multiplied to such an extent that it is becoming probable that conditions during the formation of the Coal Measures were much less local than had been supposed, and that there was, at least at certain times, comparative uniformity in freshwater areas over many thousands of square miles. Such conditions would be difficult to parallel at the present day.

Studies of the freshwater shells have been accompanied by statistical investigations of their variants. It has been shown that many bands are characterized by a 'community' of individuals which presumably were freely interbreeding. Nomenclature here presents problems of a difficult nature, and in some cases formulae have been devised for purposes of designation, e.g. by DR D. LEITCH [3].

The use of the shells, however, depends only in part on the actual naming of individual specimens. Their application to practical problems of mining may be considered in two directions. First, the division of the Coal Measures into zones, even if some of these zones are occasionally a thousand feet thick, is of great value when unknown coalfield areas are being explored by borings. For example, where the Coal Measures may be expected to exist beneath a cover of newer rocks resting unconformably upon them, as in the concealed coalfields of Kent and of Lincolnshire, no evidence as to the probable structure of the Coal Measures may be visible in the simpler structures of the overlying rocks. Even though coal-bearing strata are found immediately beneath the latter, it may be impossible to judge whether they lie somewhere near the productive coals or whether they are in fact near the base of the Coal Measures, the productive measures having been washed away from that locality before the deposition of the newer cover. This is the point where Coal Measure zoning is of importance, for fossils collected from the borehole may be sufficient to determine the position and to indicate the probable structure of the area.

Shells are of even greater importance in the more detailed work involved in the progressive development of an area where mining is already in progress, for within small regions or individual coalfield basins the shells frequently enable the geologist to recognize much thinner rock groups. In South Wales it was found possible in the anthracite area to identify many individual seams by means of the associated faunas. This is always useful when the seams in unknown ground are being developed, but it is especially important when the seams are disturbed; in some coalfields they show great irregularity, having been faulted and folded by earth pressure since the time of their formation. Mining operations may follow a seam for some distance, to find that it is suddenly cut off; its further extension at some unknown height above or below its former level can often be determined quickly from a knowledge of the faunas occurring beyond the fault. These results are being attained in practically all the British coalfields.

Work on similar lines in many Continental countries has been developed in recent years. In some, it has been based on the work of Wheelton Hind, and has yielded results which are in general of restricted use for detailed mining problems. In Russia, its applications have been fully recognized and are there widely used in the development of the great new coalfields. The Donetz basin is in some ways the most interesting of these, and here the work of TCHERNYSHEV, among others, has revealed a remarkable sequence of shells which can be closely matched with

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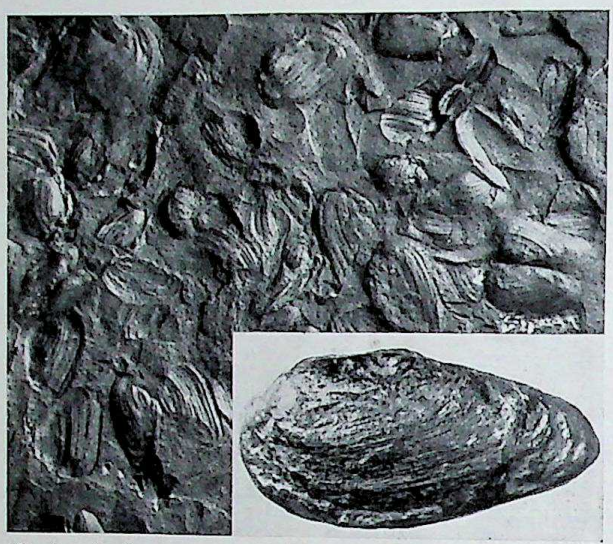
that in Britain [4]. The tracing of these bands has made it possible to secure rapidly an interpretation of the structural problems of the area. Subsequently, similar methods have been applied further east, for instance in the Kusnetz basin, where such workers as RAGOZIN and FEDOTOV have made detailed studies of the shells. These are only in part comparable with the fossils found in Britain and the Donetz, for the coal-bearing rocks are on the whole newer than the British Coal Measures, extending upwards, it may be supposed, from highest Carboniferous into the Permian. They therefore contain different types of shells, differing in genera from those dealt with here. But by following similar methods of rigorous collecting and careful analysis of slight differences the Russians have been enabled similarly to obtain information of great value in applied geology.



Carbonicola ornata. *Slab showing variation. Millstone Grit, Yorkshire. Inset:* Carbonicola atra. *South Wales (solid shell in ironstone).*

In the course of these studies renewed interest has been taken in the marine bands. It has been confirmed, as Stobbs and others indicated, that in the British coalfields such bands are few in number and that they occur at definite horizons. It has also been discovered that these horizons are equivalent in different coalfields. Four such bands may now be regarded as of outstanding importance, one occurring near the base of the Coal Measures, one in the midst of the productive measures in many coalfields, and two (one of them the Mansfield Bed and its equivalents) occurring above the more productive strata in most British areas. The occurrence of these bands, easily distinguished from the freshwater 'mussel bands,' is of some importance; not merely do they emphasize the uniformity of conditions in these areas during the deposition of the rocks, but they form useful and reliable guides, as easily recognized by a mining engineer as by a trained geologist, which may prevent errors in correlating the coals in a boring. Marine bands are more frequent in Russia, as they are also in parts of the U.S.A.

Meantime work on the fossil plants has also made much progress, and they too are being brought into greater use in coalfield work. Many of the common plant fossils, especially the larger and more obvious specimens, are frequently representatives of species which have a very long vertical range, extending with little change, it may be, through the greater part of the Coal Measures. Naturally such forms are of no use in the identification of seams. On the other hand, many of the ferns were more short-lived, and some, especially of rarer types, were found for only very short times: when available, these are comparable in value with the shells in the zonal division of the Coal Measures. Recognition of these plant zones on the Continent owes much to PROFESSORS BERTRAND (France), JONGMANS (Holland), and RENIER (Belgium), while in Great Britain DR E. DIX [5] has achieved notable results in this direction. A more restricted field of plant study—the separation from the coal itself of the spores and microspores, on the lines developed by DR A. RAISTRICK [6]—has yielded results calculated still further to increase our knowledge and to facilitate the search for coal.

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Rediffusion: a development of broadcasting

PAUL ADORJAN

The novelty of broadcast reception has long since evaporated. Listeners now demand complete fidelity of transmission and freedom from fading and distortion. With wireless transmission this ideal is frequently unattainable. Mr Adorjan describes and explains the many advantages offered by 'rediffusion,' or wire transmission, for which he predicts a great future.

Soon after the invention of the telephone, it occurred to some far-sighted people that this invention provided an excellent means for the distribution of news, education, and entertainment. The original telephone systems, in their simplest forms, were designed and operated to interconnect two points by means of wires, addition of telephone instruments and batteries at the two ends enabling conversations to be carried on in both directions. With the introduction of the telephone exchange and organized telephone systems, telephone conversations were no longer limited to two fixed interconnected points, but any one of a large number of subscribers belonging to such a telephone system could be connected to any other subscriber on the same system. It is well known that these telephonic systems have gradually developed into urban, regional, national, and world-wide systems. Before the present war, it had become possible to talk by means of the telephone to almost every inhabited part of the world.

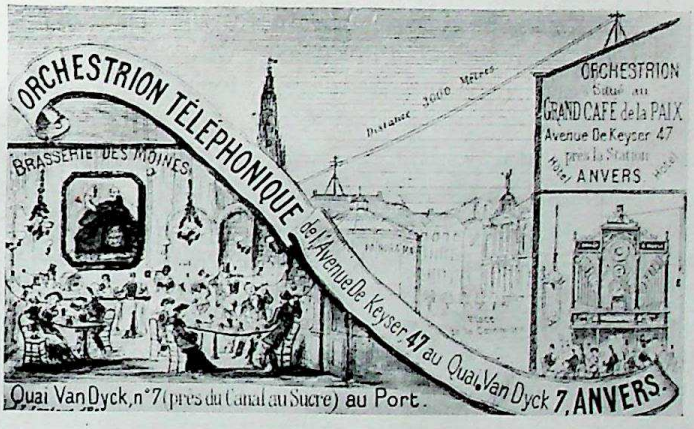
ORCHESTRION TÉLÉPHONIQUE de l'Avenue De Keyser 47 au Quai Van Dyck 7, ANVERS.
BRASSERIE DES MOINES
ORCHESTRION
GRAND CAFÉ de la PAIX
Avenue De Keyser 47
ANVERS
Quai Van Dyck, n° 7 (près du Canal au Sucre) au Port.

FIGURE 1

Since the eighties of the last century, following the improvements achieved in telephone technique, many attempts have been made in different countries to introduce the telephonic broadcasting of news and entertainment. In the simplest form, a microphone and battery were placed near some source of entertainment and connected by means of wires to some other place which was equipped with telephone receivers.

Thus entertainment, such as music, was made audible to listeners some distance away. A simple scheme of this kind is illustrated in figure 1, showing a print dated 1880. It will be seen that the music produced by the 'orchestrion' situated at the *Grand Café de la Paix* at Antwerp is being listened to by patrons at the *Brasserie des Moines* some two miles away. Other similar systems were erected in different parts of the world, and commercial organizations, sometimes associated with telephone companies, started to operate such systems on a revenue basis. The organizations concerned built wire systems with wire feeders radiating from a central point, and then connected individual subscribers to these communal feeders. It soon became apparent that, just as in the case of the telephone, the economics of the system largely depended on the subscriber density, i.e. the number of subscribers who were connected to the system in a given area. To make the system attractive, it was usual to connect the central distribution point to various theatres by means of private wire lines and thus make up programmes chosen from operas and plays which gave entertainment value by means of sound only. Periodically, news bulletins were read out from the central distribution point.

These systems, with some exceptions, did not prove a success, very largely owing to the fact that programme material was not specially prepared for presentation by sound only and therefore lost

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much of its interest. Also the technical facilities available did not allow a very high standard of reproduction, and even operas and symphony concerts lost much of their true perspective from the listener's point of view.

It would take up too much space to describe the technical details of the early systems, but the difficulties that had to be overcome in days before the invention of the thermionic valve will be appreciated if it is mentioned that when growth in the number of subscribers necessitated transmission of more electrical power, this was usually supplied by means of additional microphones at the source.

With the development of radio transmitting and receiving equipment, radio broadcasting for entertainment and educational purposes was established in nearly all parts of the world. The number of listeners became very considerable, and the revenue derived from the licences and other forms of taxation enabled the organizations responsible for the programmes to originate really good programmes specially prepared for sound broadcasting only. It was not long before the quality of broadcasts reached such a high standard that the main object in reception became clear reproduction and the novelty interest gradually faded. Thus the listening public gradually gauged programmes by their entertainment value and reality of reproduction, rather than by the distance between the transmitter and the receiver. This, except in the case of certain special programmes, is now of very little interest.

Very soon after the introduction of radio broadcasting, it was appreciated that in some industrial areas clear wireless reception was almost impossible. Also, in spite of the many improvements made by the B.B.C. in the United Kingdom and by other equivalent broadcasting organizations abroad, nearly every country has areas where reception for at least certain parts of the day or night is unsatisfactory. With the demand for alternative programmes this problem is even more serious, as still more equipment is required to give two radio programmes throughout the country.

Increased popularity of radio broadcasting brought suggestions in England and various parts of the Continent of Europe for the distribution of broadcast programmes by wire direct to the subscriber's premises, where they were to be heard by means of headphones or loudspeakers. While some of these schemes required the use of a special network, others recommended the utilization of existing networks such as the telephone and electric mains systems.

In England various methods of distribution of broadcast programmes over wire are known by the name of 'rediffusion.' Briefly, the main groups under which rediffusion systems can be classified are as follows:

(1) *Radio Frequency Rediffusion—*
On existing networks.
On special networks.

(2) *Audio Frequency Rediffusion—*
On existing networks.
On special networks auxiliary to existing network.
On special networks.

The method adopted in England has been audio frequency distribution by special networks erected for the purpose.

While various advantages can be claimed for any of the five systems listed above, only the last has been used successfully in practice. Its success can be attributed to the simplicity of the scheme, which, while giving excellent results, can be operated satisfactorily on an economic basis. In the case of the high-frequency schemes using existing networks or special networks, it is essential to have at the subscriber's house a receiver which will select the radio frequency-signal carrying the desired programme out of two or three such programmes that may be distributed along the network. The signal received has to be converted into audio frequency-signals and amplified to a sufficient level to operate a loudspeaker. Such a receiver will have three or more valves and will require connection to electricity mains or batteries.

In the case of distribution at audio frequencies by special networks, all that the subscriber requires is a programme selector switch, a loudspeaker, and a volume control. It is usual to distribute two or three programmes, using a separate pair of wires for each programme, and the duty of the programme selector switch is to connect the loudspeaker to the line carrying the programme desired. The programmes are sent down the line at a sufficiently high level to operate permanent-magnet loudspeakers at such volume as to give adequate sound output for an ordinary room.

At the time of writing there are about 400,000 homes in Great Britain obtaining their radio programmes by means of rediffusion. This

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number may seem small compared with the total of about ten million licence-holders. It must, however, be remembered that until 1939 only short-term licences were issued by the Postmaster-General to companies operating rediffusion systems, and therefore some reluctance was shown by the companies to erect new systems requiring considerable financial investment. In 1939 the Government decided to extend the licence of rediffusion companies by a further ten years, and very considerable development would have resulted had it not been for the intervention of the war, resulting in shortage of man-power and materials. In areas where rediffusion systems have been established, a large proportion of the population receives its programmes by this means. It is indeed not uncommon to find areas where one in three or even one in two houses is supplied by rediffusion.

Such programmes as are not received by direct lines between the B.B.C. studios and the rediffusion stations are received at receiving stations remote from the town, equipped with appropriately designed receivers working in co-operation with special aerial systems. These aerials sometimes spread over some hundreds of acres of ground. For example, to receive the pre-war Droitwich transmitter at Plymouth and Newcastle-upon-Tyne it was necessary to erect an aerial system half a mile long at the remote receiving station in each of these areas.

The receiving stations are attended by skilled operators whose job it is to receive the various radio programmes, working to a prearranged programme chart. They monitor the programmes and bring into operation such additional equipment as may be required from time to time. Figure 2 shows the interior of a typical remote receiving station. From the remote receiving station the programmes are sent down at audio frequencies on private wires to the rediffusion central control station. This acts as supervisory control for its particular area, which may be a small town or a fairly large area including adjoining towns, depending in each case on the particular local system.

The main function of the central control station is to distribute the programmes received from the rediffusion receiving station, and also such programmes as may be received direct from the B.B.C. studios by line, to several sub-amplifying stations placed in different parts of the area it supervises. The supervisory control apparatus provided at the central control station enables

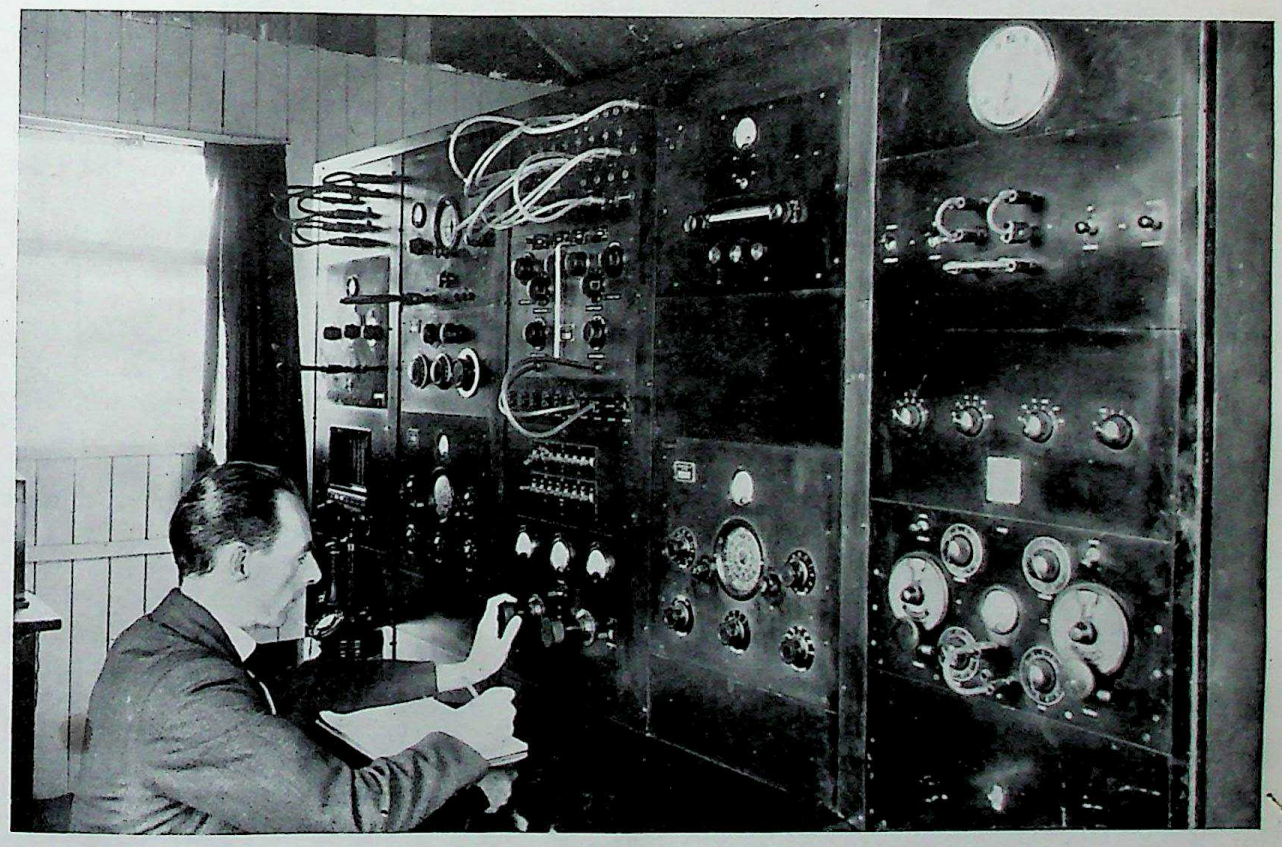

FIGURE 2

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the central control operators to listen to programmes which are being amplified and sent out from the sub-amplifying stations, and to control the level of the outgoing programmes. This is to prevent subscribers from getting too low or too high a level. Any breakdowns that may occur at these unattended sub-amplifying stations are quickly noticed by the supervisory operators, and mobile service engineers can be despatched to carry out repairs where necessary. Sufficient spares are available at substations for the immediate replacement of any equipment that becomes faulty, and there are also facilities at central control for switching equipment on and off. Certain additional facilities have been installed such as are required for the relaying of air raid warnings and special messages. Various instruments are available at central control and at substations for testing the outgoing lines, and all have to be maintained in good condition. Standby

FIGURE 3

electric power generating plant is also installed at these stations.

Individual amplifiers are capable of delivering between 100 and 1,500 watts undistorted output. The size of amplifiers used at any station is decided by the maximum load connected to that station. Figure 3 shows a typical amplifying

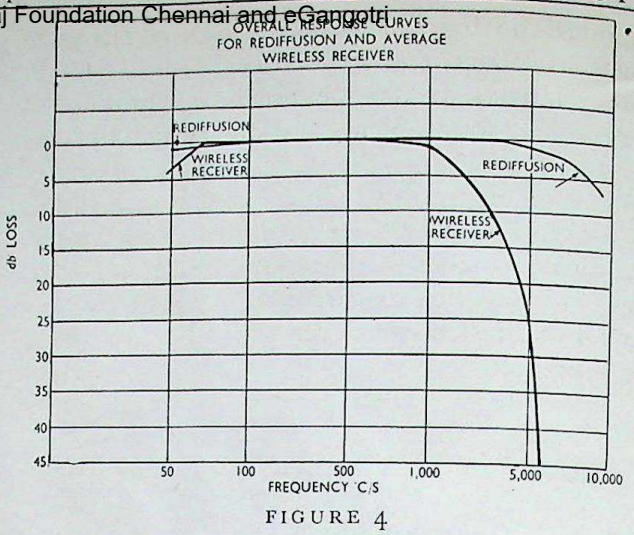

FIGURE 4

station. It is usual to distribute the programmes from the amplifying station by means of high-voltage lines to numerous transformer kiosks at which the voltage is stepped down to a lower level. The transformer kiosks are similar to the metal boxes which can be seen in streets in connection with electricity distribution, tramway control, etc. From the transformer boxes, distribution feeders radiate to the subscribers' premises.

All the distribution wires are erected and maintained by rediffusion companies. Special care is taken in this connection to design, erect, and maintain the network so that cross-talk between programmes is not audible, and that rediffusion wires shall not come into contact with Post Office or other adjoining wires. Owing to the short tenure of the licence granted by the Post Office to rediffusion companies, it has in general not been economic to install cables underground, but as far as possible rediffusion wiring systems have been made neat and unobtrusive.

In wireless reception, distortion and interference of various forms can be introduced by (1) the transmitter, (2) the medium through which the wireless waves have to travel, and (3) the wireless receiver. In rediffusion, on the other hand, by direct connection to the studio, distortion due to the transmitter is eliminated, while distortion and interference due to the intervening medium, which in the case of rediffusion is wire lines, can be made negligible in comparison with those introduced under average conditions with wireless. The third type of distortion, namely that due to the receiver, can be completely eliminated in the case of rediffusion except for such distortion as may be introduced by the loudspeaker itself.

Even in cases where direct lines are not available from the broadcasting studios to the rediffusion

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stations, the directional and diversity aerials with their associated special equipment, installed at sites relatively free from interference, ensure considerable improvement on ordinary wireless reception.

The following table shows a comparison between ordinary broadcast wireless reception, a rediffusion system which receives its programmes by a wireless link at a remote receiving station, and a rediffusion system connected by direct lines to the studio:

Type and Cause of Distortion or Interference	Ordinary Wireless Reception	Rediffusion System depending on special Wireless Reception (Remote Receiving Stn.)	Rediffusion System utilizing direct wire channel from studio
Transmitter— Frequency discrimination. Harmonic distortion. Noise.	Depending on design of broadcast transmitter. Quite noticeable on some transmitters.		Not present. Additional line repeaters introduce only negligible noise and distortion.
Transmitting Medium— Fading (with or without distortion). Electrical interference. Interference from other transmitters.	Depending on local conditions. Except when near to transmitter is very bad on occasions.	Reduced to very small level by the special directional and diversity aerials and equipment used.	Not present. Line noise and distortion negligible.
Receiver— Frequency discrimination.	High notes attenuated to reduce interference.	Much less attenuation of high notes as aerial system with associated equipment gives sufficient reduction of interference. Frequency discrimination introduced by rediffusion feeders small compared with radio receivers.	Not present.
Second channel interference (superhets.). Valve noise. Harmonic distortion.	Usually not bad when receiver is new but gradually deteriorates.	Owing to daily maintenance by skilled engineers kept at very low level.	Not present.
Loudspeaker	Common to all systems		

While the above table gives a general qualitative view, figure 4 shows a quantitative comparison for frequency discrimination of a commercially produced wireless receiver and a complete rediffusion system, including the line amplifiers, power amplifier, interconnecting line and rediffusion network. It will be seen from this that very considerable loss of the higher frequencies occurs in broadcast receivers, while in the rediffusion system no undue loss occurs. It is appreciated that it is possible to make wireless receivers with considerably better high-frequency response than that shown in figure 4 (and such receivers are used at rediffusion remote receiving stations), but the use of receivers with improved high-frequency response is quite useless unless aerial systems requiring considerable space and a site free from interference can be utilized. If such an aerial system is not available, considerable interference can be expected even on a high-quality receiver. Figure 5 shows the overall response curve of a special receiver such as is used at rediffusion remote receiving stations. As regards harmonic distortion, by frequent measuring tests it is possible to keep rediffusion equipment in such condition as to limit the total voltage harmonics introduced to 5 per cent., which is generally accepted as a suitable upper limit. In the case of broadcast receivers also, this figure can be attained; but in practice it is found that distortion usually increases with the ageing of valves, and unless frequent checks are made and valves that have aged are replaced, such a distortion limit cannot be maintained.

One of the great advantages of rediffusion as compared with wireless reception is the almost complete absence of interference and background noise on rediffusion; and while a signal-noise ratio of 20 decibels is considered acceptable for wireless reception, in most industrial areas a signal-noise

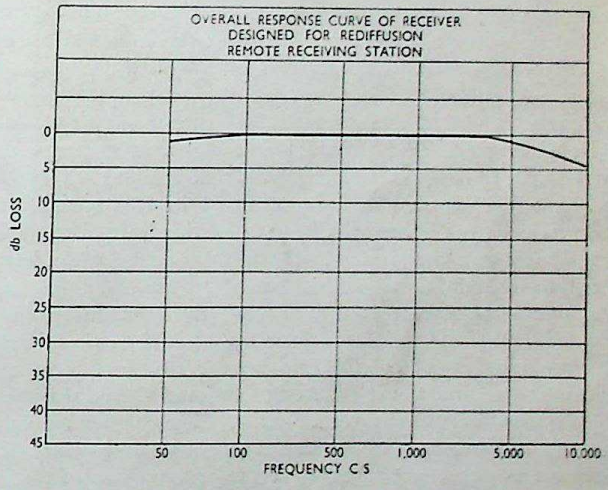

FIGURE 5

ratio of the order of 40–55 decibels is achieved by rediffusion systems without sacrifice of high-frequency response.

In view of the great advantages of wire over wireless, particularly for the distribution of broadcast programmes in densely populated areas, there can be little doubt that this method will be employed in an increasing proportion of homes. There is, moreover, no technical reason why it should not be used in future for distribution of broadcast programmes in rural areas.

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BIOLOGY, CHEMISTRY, AND LIGHT

Living Light, *by E. Newton Harvey. Pp. xv + 328. Oxford University Press, London.* 1941. 24*s. net.*

The Chemical Aspects of Light, *by E. J. Bowen. Pp. vi + 191. Oxford University Press, London.* 1942. 12*s.* 6*d. net.*

Little excuse is needed for associating these three topics. The Biblical account of the Creation opens with the noble first fiat 'Let there be light,' and modern science has explored some but not all of the intricate ways in which the existence of living creatures depends upon the light which falls upon this planet. Light is one of the first sensations we experience when we enter the world as individuals, and from infancy to old age we rely on photochemical changes in the visual purple of the eye for most of the information we gather concerning the universe around us. The two volumes under review may be regarded as a modern commentary on this theme. They supplement one another to a considerable extent since DR HARVEY deals mainly with the emission of light by living creatures, whilst MR BOWEN outlines the picture which modern theory presents of the nature of light and of its interaction with both dead and living matter.

Dr Harvey's book is unusual and attractive. It contains an account of the biology, chemistry, and physics of the production of light by living creatures ranging in complexity from bacteria to fishes. It is written with scientific accuracy, it is fully documented, and the exposition is aided by a large number of careful drawings and photographs. Yet it is a book for the layman as well as the scientist, since it is written in a style which is as effective as entertaining. Some of the happier phrases which enliven the more severe parts of the volume may be quoted: 'Luminous organs have often been mistaken for eyes. The reason is obvious: they are eyes in reverse. Chemical production of light is the converse of the chemical detection of light.' Later in the same chapter comes: 'The smallest lamps in the world, luminous bacteria. . . .'

The opening chapter is largely historical and contains a curious quotation from BOYLE on the cause of luminosity of the sea. Then follow a critical survey and description of the organisms in which luminosity has been observed. Bacteria, jelly-fish, glow-worms, fireflies, and a wealth of strange creatures from the deeper seas are passed in review. A limitation in their distribution in Nature is noted: practically all of them are marine or terrestrial *animals*. Of plants, only bacteria and fungi exhibit luminosity, and the only freshwater organisms which are luminous are bacteria and an aquatic glow-worm.

The firefly and the glow-worm have inspired many poets, but two humbler and less well-known creatures have been most useful in elucidating some steps in the chemistry of light emission The rock clam, *Pholas dactylus*, was studied by DUBOIS who, sixty years ago, demonstrated the presence in its light-producing organs of a heat-labile enzyme, luciferase. This acts on a more stable substance, luciferin, with the emission of light. The small crustacean *Cypridina hilgendorfii*, only an eighth of an inch in length, is caught by Japanese fishermen using a fish-head as bait. If rapidly dried it can be kept for years and will still luminesce when moistened. From dried *Cypridina* a luciferin and a luciferase have been prepared by HARVEY, and later in purer condition by ANDERSON. These preparations are remarkably active, the luciferin giving a detectable emission of light at a dilution of the order of 1 in 10^{11} when *Cypridina* luciferase is added. Luciferin is not a protein; it is thought by Anderson to be a polyhydroxybenzene derivative of relatively low molecular weight.

Many other interesting topics discussed in this volume must be passed over—three may be briefly mentioned. The chapter on physiology contains an interesting discussion of the reflex mechanism of the flashing of fireflies. In a later chapter the overall efficiency of a luminous bacterium as a light-producer is computed to be 0·16 per cent. 'This tells us what percentage appears as light of all the energy required to run a bacterium.' The last chapter includes a review of the work on mitogenetic rays which are supposed to stimulate cell-division. There is a shrewd summing up: 'Indeed, the whole story is so fantastic, the findings of the investigators are so contradictory, . . . and statements of the properties of mitogenetic radiation are so at variance with what is known of the nature of ultra-violet light that it is impossible to make logic out of the reports.'

Mr Bowen's volume is rather stronger meat, but it well repays a close study. It is an attempt to present the concepts used in the theory of light and its interaction with matter without using a formal mathematical treatment. The main stress is laid on the ideas which form the basis of physical theory and the subject is developed systematically, starting with an account of the properties of light. Next comes a discussion of emission and absorption by atoms and molecules, which introduces the quantum theory and the theory of spectra. This is followed by an account of modern views on the transformation of absorbed radiation, i.e. of fluorescence and luminescence. The remainder of the book is concerned with more detailed applications of the general theory to photochemistry, photosynthesis in plants, the theory of the photographic plate and so on.

Two features of the treatment call for special mention. Mr Bowen throughout keeps his feet firmly on the ground of objective facts and refuses to be carried aloft by semi-philosophical interpretations of mathematical theories. After some of the claims which have been made for the application of quantum theory to chemical problems it is refreshing to find such statements as the following: 'Wave mechanics, while providing a unified interpretation of quantum phenomena in atoms, quantitatively correct for very simple systems, is held up by mathematical difficulties from further extensive advance of a numerical kind.'

The other notable feature of the book is the stress which is laid on experiment. The discussions are illustrated by a wealth of accurate numerical data, while valuable practical information about light sources, filters, the preparation of phosphors, etc., is contained in the text and the appendices.

S. SUGDEN

ORGANIC FORM

On Growth and Form, *by Sir D'Arcy Wentworth Thompson. Pp. vi + 1116, with 2 plates and 554 figures. University Press, Cambridge. New and revised edition*, 1942. 50*s. net.*

Since its first issue in 1916 this book has grown, by intussusception, from 793 to 1116 pages; but the form is

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still the same. New work is used as further variation on a theme composed a quarter of a century ago. The incorporation is skilful, and only reference to the dates quoted enables the reader to detect the joins.

JULIAN HUXLEY on growth ratios, BERNAL on protein molecules, RIDEAL on monolayers, and many others make their appearance; but *Growth and Form* need not be read for its account of recent advances. It is a biological classic because of its unique assimilation of earlier work. Though the classical foundations are the author's peculiar domain, it is, perhaps, his draft on the speculation and experiment of later centuries which is most valuable. Biologists who have of necessity spent much time on the most recent work, to the neglect of that published before 1850, will find their perspective corrected by an occasional evening with a chapter of this book. They will make contact with a ripe and cultured mind and they may be surprised by both the depth and the liveliness of earlier thought on a great variety of biological topics.

SIR D'ARCY THOMPSON moves easily through the fields of classics, mathematics, and biology. If his lucidity sometimes makes things appear easier than they are, it is a quality of style not shared by many. His attitude is expressed in a sentence of the Epilogue: 'I know that in the study of material things, number, order, and position are the threefold clues to exact knowledge.' We welcome a modern edition of this great work and congratulate the author on the completion of a heavy task.

MACGREGOR SKENE

ANALYSIS OF THE ELEMENTS

Mass Spectra and Isotopes, *by F. W. Aston. Pp. xii* + 276, *with* 12 *plates and* 48 *figures. Edward Arnold & Company, London. Second edition*, 1942. 22*s*. 6*d*. *net*.

'All the elements have now been analysed' isotopically, says the author in his preface to the second edition of this book, 'and my main concern . . . is to tell how this has been done.' We may appreciate the quiet but intense satisfaction that went to the penning of these lines, for they imply the completion of an arduous and intricate task of which the main burden has fallen upon DR ASTON himself. As Englishmen, we may feel an equal, if vicarious, satisfaction that in an investigation of such fundamental importance this country has played a leading part. The first edition of Dr Aston's book is familiar to all physicists and all chemists in all parts of the world. The present edition will also achieve ubiquity, since it is indispensable. It contains a completely new chapter on modern mass spectrographs, including the double focusing types of DEMPSTER, BAINBRIDGE and JORDAN, and MATTAUCH, and Jordan's high dispersion instrument, which has a resolving power of 30,000. The third part of the book, which deals with nuclear chemistry, includes the whole of the evidence upon which the first International Table of Stable Isotopes was drawn up in 1936, together with an account of later work. The text throughout has been revised and brought up to date, and a comparison of the two editions reveals the astonishing progress made during the last decade.

A TEXTBOOK OF ATOMIC PHYSICS

Introduction to Atomic Physics, *by S. Tolansky. Pp. x* + 343. *Longmans, Green & Company, London*. 1942. 15*s*. *net*.

There was—and is—a real need for a book of about this size and scope, treating atomic physics from the modern viewpoint. Dr Tolansky's book is written for second and third year university degree students who have not begun to specialize. There is no fault to be found with his selection and arrangement of material; in fact, Dr Tolansky is to be congratulated on having so satisfactorily solved this problem, which is of special importance in the presentation of a rapidly developing subject. This intensifies the reviewer's disappointment in finding that a work so well planned should be marred by so many faults in execution that it cannot be recommended to students.

There are many errors in the diagrams and the text. Many of them are trivial, and many would be detected at once by any fairly good student. There are, however, some which are particularly objectionable, inasmuch as they are of a kind to perplex the only type of student worth considering — the one who wishes to understand and to apply, and not merely to reproduce in examinations, what is put before him. A bad example of this is the statement that the numerical prefix in a number of named spectral terms, such as the sodium *1s* term, represents the associated total quantum number. A student who is pursuing the subject intelligently may suffer a great deal of bewilderment before he finds out that the statement is simply not true. A very similar criticism applies to a singularly infelicitous pseudo-derivation of the CHILD-LANGMUIR relation (pp. 100–102), which can only confuse any reader who is given to respecting the authority of the printed page.

It is probable that the book will sell, and that Dr Tolansky will have an early opportunity of preparing a second edition. If he is prepared to revise the text critically and very drastically, he may make a book which will be of real use to students —and this could be done without any large alteration in the general plan of the work. H. R. ROBINSON

CHROMOSOME TECHNIQUE

The Handling of Chromosomes, *by C. D. Darlington and L. F. La Cour. Pp.* 165. *George Allen and Unwin Limited, London*. 1942. 8*s*. 6*d*. *net*.

The study of chromosomes, in spite of the great importance attached to them, was pursued until recently only by a small group of experts, who made numerous valuable and fundamental theoretical advances with far-reaching and often unexpected implications. We know now how life in its three main aspects—reproduction, development, and heredity—is controlled by the chromosomes. Improvements in technique underlie the rapid progress, and by making the technique of chromosome-handling in its varied ramifications available to scientists, the authors of this well-produced and lavishly illustrated book have done a great service and have given an impetus to further research. Many will welcome the book and profit by it. It will certainly help to rectify the profound errors which, the authors claim, have kept many investigations, e.g. X-ray work on human cancer, outside the boundaries of objective science. It is furthermore obvious that if we are ever to succeed in unravelling and in understanding the complexities of chromosome structure and behaviour, and in controlling the main processes of life, a close integration of cytology, chemistry, and physics is not only desirable but necessary. The scientific value of this book lies in its important contribution to this goal. P. C. KOLLER

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Is Physiologist of the Animal Nutrition Institute in the University of Cambridge and a Fellow of Downing College. Born in 1889, he is the son of a Norfolk farmer and grandson of one of the foundation members of the Red Poll Cattle Herd-book. After taking a degree in Natural Sciences at Cambridge, he studied agriculture under Professor T. B. Wood and later specialized in the physiology of farm animals. He has applied modern scientific knowledge to such problems of animal husbandry as breeding, fertility, growth, and meat production, and has published numerous papers and books on these subjects. A member of many learned societies, both British and foreign, he was Guest Professor of Animal Production and Physiology at Iowa State College, Ames, Iowa, U.S.A., in 1932. He has travelled widely in order to study at first hand conditions of animal production in many different countries. Investigated problems of cattle-breeding in the tropics (West Indies) for the Empire Marketing Board, and has seen something of the same problems in Fiji, Ceylon, and Brazil. At the request of the New Zealand and Australian Councils of Scientific and Industrial Research visited these countries to survey their animal industries. Went to the Argentine to see the methods of beef and lamb production and to advise the Argentine Corporation of Meat Producers on scientific methods. His scheme for judging the suitability of Argentine lamb carcasses for the British market proved so successful that it was also adopted by Uruguay, while Australia, New Zealand, the British Dairy Show, and the National Pig Breeders' Association employ the methods he suggested for judging pork and bacon carcasses.

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Was born in Monmouthshire in 1896, though he is a Scotsman by race. After some years in the Regular Army, he entered University College, London, in 1920 and carried out research under Professor W. E. Garner on the heats of adsorption of gases by charcoal. Later he turned from physical chemistry to the history of chemistry, and is now Lecturer in the Department of the History of Science in the University of London. He has written many papers on the history of chemistry, and in 1935 published an authoritative biography of Lavoisier. His *Discovery of Specific and Latent Heats* (in collaboration with N. Heathcote) established the priority of Joseph Black's work in this field. He is one of the founders and editors of *Annals of Science*, a quarterly journal dealing with the history of science in the modern period.

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Born in 1886 in Bolton, Lancashire, he is a North Countryman of English as well as Scottish origins, and claims to combine many of the characteristics of each. He graduated at Manchester University, where he studied under H. B. Dixon, and later carried out post-graduate work in physical chemistry and thermodynamics in the University of Berlin under Nernst and Planck. He returned to Manchester as a member of the staff of the University Chemical Department, and from 1914 to 1919 served in the Army and the Ministry of Munitions. Since 1919 he has been Professor of Chemistry in the University of London (Queen Mary College). He has published numerous papers and books on inorganic and physical chemistry, thermo-dynamics, the alkali industry, the specific heats of gases, and chemical mathematics. Has a wide knowledge of the history of chemistry, to which subject he has extensively contributed. His *Origins and Development of Applied Chemistry* covered the vast field of the hitherto unexplored prehistory of chemistry.

C. F. POWELL,
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Was born in 1903 and educated at the Judd School, Tonbridge, and Sidney Sussex College, Cambridge. From 1925 to 1927 he was engaged in research at the Cavendish Laboratory under C. T. R. Wilson and Lord Rutherford, investigating supersaturation phenomena and applying the results to problems of steam engineering, especially the anomalous discharge of steam through nozzles. Later he collaborated with Professor A. M. Tyndall, at the University of Bristol, in work on the mobility of ions in gases. In 1936 he was appointed Physicist to the expedition, organised jointly by the Colonial Office and the Royal Society, to Montserrat (B.W.I.) for the investigation of seismic activity in the islands constituting the Caribbean arc.

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Was born at Nottingham in 1894 and educated at the University College of that city. He has been Professor of Geology in Wales (Swansea, 1920–33), England (Bristol, 1933–37), and Scotland (Glasgow, 1937–). His early research dealt with the Jurassic rocks and the more theoretical aspects of palaeontology; but in South Wales he began investigations on coalfield geology, with results that have been applied to all British coalfields. They are proving of increasing importance in solving the structural problems affecting coal-mining. For many years he has endeavoured to secure a wider recognition of geology in school and university curricula, and has written several popular books on the cultural aspects of the subject. He is a medallist of the Geological Society and of the South Wales Institute of Engineers.

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Was born in 1905, and received his electrical engineering training at the City and Guilds (Engineering) College, London. He joined Rediffusion Limited in 1932 as Development Engineer, and became Chief Engineer in 1936. Since 1941 he has been Technical Director of Broadcast Relay Service Limited. In 1941 he spent five months in America in connection with the organization of his company's Canadian subsidiaries for war production. He has published several technical papers relating to radio communication and rediffusion (wire-broadcasting). As founder of the Imperial College Gliding Club, he took an active part in gliding up to about ten years ago.

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